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Knowledge of the Female Athlete Triad and Relative Energy Deficiency in Sport Amongst Female Distance Runners and Their Support Staff

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ABSTRACT

There has been an increased participation of female athletes competing in the NCAA for the past thirty years. Amongst these female athletes, there is an increased risk of stress fracture (SFx) injury, which is highly prevalent among female endurance sports. Female athletes, especially those participating in endurance sports (i.e. distance running), exhibit an increases risk of developing The Female Athlete Triad (the Triad) and Relative Energy Deficiency in Sport (RED-S). The Triad and RED-S are conditions that explore the health and performance consequence of low energy availability (LEA) amongst athletes. Few studies to date have assessed the knowledge that athletes, coaches, and athletic trainers have regarding the triad and RED-S. Proper education and knowledge have been shown to be effective in properly addressing other sports medicine concerns in athletes, yet the current recommendations for continuing education for the triad and RED-S are not required by institutions. **PURPOSE:** The primary purpose of this study was to assess the knowledge and confidence of identifying, screening, treating, and preventing the Triad and RED-S via knowledge, confidence, and a composite impact score. Scores were assessed amongst collegiate female distance runners, coaches of collegiate female distance runners, and athletic trainers (ATs) of collegiate female distance runners. **HYPOTHESES:** It was hypothesized that female distance runners will demonstrate the lowest scores (confidence, knowledge, and impact) regarding the Triad/RED-S. While it is hypothesized ATs will demonstrate the highest scores regarding the Triad/RED-S. **METHODS:** Two-hundred-sixty participants completed this study: 175 collegiate female distance runners (age 20 ± 1, 175 female), 55 coaches of collegiate female distance runners (age 36 ± 11, 29 male, 26 female), and 30 ATs (age 34 ± 9, 26 female, 3 male). The Triad and RED-S questionnaire was developed and used to assess the knowledge and confidence (37-items) of the triad and RED-S

through a series of questions targeted at the identification, screening, treatment, and prevention of the Triad and RED-S models. Other questionnaire items were included to understand interactions between participants characteristics and total impact scores, as well as to characterize the current and continuing education of participants regarding the triad and RED-S. Between group differences were assessed using a one-way ANOVA. Scores of knowledge, confidence, and impact were assessed by categorical and continuous variables using independent samples T-test and Pearson's and Spearman's correlations, respectively. Univariate GLM was used to assess interactions of participant characteristics to impact scores in a multivariate approach. **RESULTS:** Scores of knowledge, confidence, and impact were highest in ATs and lowest in female distance runners. Female distance runners' total knowledge, confidence, and impact scores (mean scores of 25.00 ± 5.27, 95.42 ± 28.83, 18.81 ± 7.05 respectively) were significantly different from the total knowledge confidence, and impact scores of coaches (mean scores of 26.92 ± 5.02, 111.35 ± 24.14 and 22.41 ± 6.33) and ATs (mean scores of 28.66 ± 4.02, 117.67 ± 22.53, and 23.93 ± 5.69) ($p < 0.05$). There was a weak, but significant correlation between peak career mileage and impact scores in female distance runners ($r = 0.195$; $p < 0.05$). Impact scores significantly differed in female distance runners with a related academic area of study compared to female distance runners with an unrelated academic area of study (mean scores of 21.91 ± 5.16, 16.11 ± 5.54, respectively; $p < 0.01$). Impact scores significantly differed in female distance runners at NCAA DI institutions (19.98 ± 7.05) versus non-DI institutions (mean score of 17.35 ± 6.82) ($p < 0.05$). Impact scores significantly differed in female distance runners with positive Triad and RED-S diagnosis (mean scores of 21.69 ± 5.85 and 22.58 ± 6.82, respectively) compared to negative Triad and RED-S diagnosis (mean scores of 16.80 ± 6.54 and 17.20 ± 6.34, respectively). Impact scores significantly differed in coaches at NCAA DI

institutions (mean score of 24.13 ± 4.57) versus non-DI institutions (mean score of 20.35 ± 7.55) ($p < 0.05$). With respect to receiving educational programming on the Triad and RED-S provided by the athletic department, 69.32% of female distance runners, 52.63% of coaches, and 51.61% of ATs report receiving no educational programming. Impact scores significantly differed in female distance runners who received training on the Triad (mean score of 21.03 ± 6.86) vs. female distance runners who did not receive training on the Triad (mean score of 18.12 ± 6.82) ($p < 0.05$). Impact scores significantly differed in coaches who received training on the Triad (mean score of 25.10 ± 4.50) vs. coaches who did not receive training on the Triad (mean score of 20.99 ± 6.75) ($p < 0.05$). 77.59% of female distance runners, 70.18% of coaches, and 40.00% of ATs reported not receiving training on RED-S. Impact scores significantly differed in coaches who received RED-S training (mean score of 25.81 ± 4.41) vs. coaches who did not receive RED-S training (mean score of 21.02 ± 6.52) ($p < 0.01$). Multivariate analysis, in female distance runners, revealed a non-significant interaction between peak career mileage and division level participation ($p > 0.05$; Table 18; Figure 7) and a significant interaction between peak career mileage and Triad diagnosis ($p < 0.05$; Table 18; Figure 8). **CONCLUSION:** This study illustrates that knowledge of the Triad and RED-S was lowest in female distance runners compared to coaches and ATs, represented by total knowledge and impact scores. Knowledge of the Triad and RED-S was highest in ATs compared to coaches and female distance runners, expressed by total knowledge and impact scores. This is important because female distance runners who are knowledgeable about the Triad and RED-S may more readily seek out medical help to address subsequent health and performance consequences related to the Triad and RED-S. This study suggests that participant characteristics had little effect on total scores (confidence, knowledge, and impact). However, significant differences that were revealed often related to

education-based and diagnoses differences (i.e. Triad and RED-S training, related academic area of study, and positive Triad and RED-S diagnoses). Multivariate analysis revealed an important interaction between peak career mileage and Triad diagnosis in female distance runners, suggesting that a positive Triad diagnosis depends on peak career mileage. These findings are in support of educational training, which should be considered as the primary tool to increase knowledge in all population groups in order to improve the prevention and treatment of the Triad and RED-S, ideally prior to the development of the Triad and RED-S.

Knowledge of the Female Athlete Triad and Relative Energy Deficiency in Sport Amongst Female Distance Runners and Their Support Staff

by

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Glossary of Abbreviations:

The Triad = Female Athlete Triad

RED-S = Relative Energy Deficiency in Sport

ATs = Athletic Trainers

BSI = Bone Stress Injury

SFx = Stress Fractures

BMD = Bone Mineral Density

NCAA = National Collegiate Athletic Association

NAIA = National Association of Intercollegiate Athletics

LEA = Low Energy Availability

EA = Energy Availability

RD = Registered Dietitian

Synopsis of the Current Study

The Female Athlete Triad (the Triad) and Relative Energy Deficiency in Sport (RED-S) are models that demonstrate the consequences of low energy availability, specifically in athletes[1–4]. Females participating in endurance sports have an increased risk of stress fractures (SFx) and bone stress injuries (BSI), compared to their male and other sport counterparts[5]. The risk of SFx and BSI is further increased in the presence of the Triad and RED-S[6]. Beyond the development of SFx and BSI, there are several other health and performance consequences associated with the Triad and RED-S. The associated health and performance consequences of the Triad and RED-S can impact the health of athletes for the rest of their life, such as an inability to recuperate associated losses in bone mineral density and consequently osteoporosis. Proper education and knowledge have been illustrated in sports medicine to be effective in increasing awareness and knowledge of other important clinical concerns such as sports nutrition and concussions awareness[7,8]. Knowledge translation of the Triad and RED-S will provide more effective healthcare[9]. Resources that enhance knowledge translation, such as evidence-based educational training, increase the clinical practitioners' ability to properly intervene, treat, and prevent the Triad and RED-S in athletes. However, few studies have assessed the knowledge of the Triad and RED-S amongst athletes, coaches, and ATs. There are no current requirements for continuing education of the Triad and RED-S amongst these populations. This study aims to assess the knowledge and confidence of collegiate female distance runners, coaches, and ATs with regards to the Triad and RED-S, as well as the role of participant characteristics on differences in knowledge, confidence, and impact scores. Additionally, current and continuing education of the Triad and RED-S in collegiate female distance runners, coaches, and ATs will be characterized.

Chapter I: Introduction

The incidence of female athletes competing in the NCAA has continued to rise throughout the past thirty years. The most recent figure illustrate that 43.4% of NCAA athletes identify as female[10]. Within this cohort of female athletes, across all NCAA-sanctioned sports, the prevalence of stress fracture (SFx) is greatest among endurance sports. Female cross-country runners, participating in distance running training, report the highest occurrence of SFx[5]. A 2017 study reported an incidence of 1.35 SFx per female cross-country team, per year[6]. Many studies have demonstrated an increased propensity of bone stress injury (BSI), inclusive of SFx, in the presence of the Female Athlete Triad (the Triad) and Relative Energy Deficiency in Sport (RED-S)[6]. The Triad and RED-S are both conditions that illustrate the health and performance consequences in the presence of insufficient energy intake amongst athletes.

A prospective study reports a BSI incidence of 11% amongst participants, reporting the highest occurrence in distance running, with a significant rise in BSI incidence in participants presenting with the Triad (3). The presence of one factor of the Triad, increased BSI incidence to 15-21%, two factors increased BSI incidence to 21-30%, and the presence of all three factors increased BSI incidence to 29-50%[6].

Current research supports the importance of proper prevention and intervention, accomplished through educational training, to treat these conditions, or components of these conditions, in order to help protect against BSI and other health-related consequences in athletes [1–4,11–18]. Fewer studies, however, demonstrate the education received and subsequent knowledge that athletes, coaches, and ATs have surrounding the Triad and RED-S. Studies that have assessed knowledge illustrate a general lack of knowledge of the Triad amongst ATs[13,15,19] and an even greater lack of knowledge amongst coaches[19–22]. Very few studies present data on the knowledge of the athletes themselves[23]. Knowledge in the support staff of athletes, such as

coaches and ATs, has been demonstrated as not only important, but effective, in properly treating and preventing conditions and consequently reducing risk of BSI[12,22,23].

Limited studies to date (May 2020) have collected knowledge, confidence, and education on the Triad and RED-S from athletes and support staff in one study design. Since the expansion of the Triad to RED-S, there is no available research on the knowledge of both the Triad and RED-S. This study seeks to update the literature on both the Triad and RED-S, regarding knowledge, confidence, and education. Data regarding participant characteristics, knowledge, and continuing education of the Triad and RED-S will be collected from three population groups: collegiate female distance runners, coaches of collegiate female distance runners, and ATs of collegiate female distance runners in order to better understand the role of mechanistic variables on knowledge, as well as to inform future research, institutional practices, and education.

As participation in female athletics increases, so does the prevalence of BSI and other health conditions; understanding the knowledge and confidence of the Triad and RED-S held by the study population groups is extremely important. Due to the increased prevalence of the Triad and RED-S in female endurance sports, female distance runners and their support staff are a valuable group to study. Not only can female distance runners benefit from this research, but if knowledge is limited in those working in and around this population, the possible implications of a lack of knowledge on the Triad and RED-S in less susceptible populations (e.g. female team sports) may be even more drastic. In populations with a lack of knowledge on the Triad and RED-S, fewer athletes are likely to receive proper intervention and treatment, increasing the susceptibility to suffer from the health and performance consequences of the Triad and RED-S. This study will seek to explore the knowledge, confidence, and continuing education of collegiate female distance runners, coaches, and ATs with regards to the Triad and RED-S. In

addition, this study will examine the role of participant characteristics (sex, age, years of experience, mileage, BSI incidence, division level participation, academic area of study, and coaching position), in each population group, on total impact scores. Since few studies have resulted in proposed strategies to address a knowledge gap, an additional goal of this study is to assess the current education of participants and collect exploratory information regarding confidence, institutional/team policies, and access to better understand and inform next steps as it relates to education, institutional practices, and future research.

Specific Objectives and Expected Outcomes of Thesis Study

Specific Objective 1: To assess the knowledge and confidence of the Female Athlete Triad (the Triad) and Relative Energy Deficiency in Sport (RED-S) amongst collegiate female distance runners, coaches of collegiate female distance runners, and athletic trainers (ATs) of collegiate female distance runners. Knowledge was operationally defined as correct answers provided on a questionnaire that surveys key theoretical constructs of the Triad and RED-S, considering identification, screening, treatment, and prevention. Confidence was assessed on a self-reported basis, on a scale from 0 – 4. A total impact score representing both knowledge and confidence simultaneously will be calculated from questionnaire data. Questions specific to the Triad and specific to RED-S were assessed separately in order to reveal any significant differences in knowledge and impact of the Triad and RED-S.

- *Expected Outcome 1:* Female distance runners will express the lowest scores on confidence, knowledge, and impact regarding the Triad and RED-S of all study population groups. It is expected that ATs will express the highest scores on confidence, knowledge, and impact demonstrating greater knowledge and confidence regarding the Triad and RED-S. It is also hypothesized that participants will score higher in the knowledge and impact of questions specific to the Triad compared to the knowledge and impact of questions specific to RED-S, because the development and research of the Triad model (proposed in 1992) precedes RED-S, which was proposed in 2014.

Specific Objective 2: To examine the role of participant characteristics (sex, age, years of experience, mileage, BSI incidence, division level participation, academic area of study, coaching position, and Triad/RED-S diagnoses) as it relates to participants' total knowledge,

confidence, and impact scores regarding the Triad and RED-S in both univariate and multivariate approaches.

- *Expected Outcome 2:* Significant relationships will be revealed by participant characteristics and total scores (knowledge, confidence, and impact) obtained by participants. It is expected that certain variables will be associated with higher knowledge, confidence, and impact scores; such as female sex, higher mileage, related academic area of study, greater BSI prevalence, positive Triad/RED-S diagnoses because these variables may likely lead to increased awareness of the Triad and RED-S. It is also expected that other variables will be associated with lower impact scores, such as male sex, increase years of experience in coaching or AT, unrelated academic area of study, because it is less likely for these populations to have exposure to the Triad and RED-S during their education.

Specific Objective 3: To characterize the current and continuing education of each subgroup with respect to the Triad and RED-S.

- *Expected Outcome 3:* A majority of collegiate female distance runners and coaches of collegiate female distance runners will not have formal educational training in Triad and/or RED-S, with 50% or less of these subgroups participating in continuing education directly related to the Triad and/or RED-S. It is expected that ATs will have received formal education of the Triad and RED-S, but that very few (10% or less) are currently required to take place in continuing education directly related to the Triad and/or RED-S.

Chapter II: Literature Review

The following literature review will introduce the concepts related to 1) the Female Athlete Triad (the Triad) and Relative Energy Deficiency in Sport (RED-S); 2) the prevalence in female endurance athletes; 3) clinical recommendations for treatment and prevention; and 4) knowledge translation in similar populations. This review provides rationale for a study to examine the knowledge and confidence of female distance runners, coaches, and ATs regarding the Triad and RED-S. This review seeks to illustrate the current knowledge provided by the literature and this study seeks to reveal the disparity in knowledge that is possessed in these sub-populations.

The Female Athlete Triad (the Triad).

The American College of Sports Medicine (ACSM) published a 1992 position statement which identified the Triad as the interrelationships among disordered eating, amenorrhea, and osteoporosis in exercising females. The Triad was established as a health concern for active women and girls, especially for those in sports that emphasized lean physiques. In 2007, the ACSM updated its position stand regarding the Triad, expanding understanding, screening, diagnoses, prevention and treatment of the Triad. The current triad model, proposed in 2007, consists of interrelationships among: 1) low energy availability (with or without disordered eating/an eating disorder); 2) low bone mineral density (BMD); and 3) menstrual irregularities *(refer to Figure 1)*[24]. A 2012 study reported a 1-4% prevalence of the Triad in athletes competing in sport. However, this figure is only representative of female athletes presenting with all three factors of the Triad[17]. The updated Triad model does not require the co-presentation of all three Triad factors to be considered a full diagnosis[17]. Therefore, the 1-4% Triad prevalence is likely to be severely under-reported. There has been no updated study reporting on the prevalence of

the Triad in athletes reporting one or more of the Triad factors. However, it is estimated that the incidence of one or two concurrent components of the Triad is approximately 50-60% in athlete groups[25]. The Triad is a concern for female athletes due to its negative consequences on health and performance[1]. Athletes shown to exhibit increased risk for developing the Triad are athletes who restrict dietary energy intake, exercise for prolong periods, limit types of foods, exhibit dieting tendencies, specialize early in sport, experience injury, acutely increase training volume, amongst other risk factors. In the 2007 position stand, the ACSM provides recommendations for prevention and treatment of the Triad[1]. The recommendation includes a multidisciplinary treatment team consisting of a physician, a registered dietitian, and, for athletes presenting with disordered eating or an eating disorder, a mental health practitioner[1]. The proposed prevention strategies include education regarding the Triad for athletic administrators, as well as the healthcare team[1]. The ACSM suggests procedures and policies are enacted by the national and international governing bodies at sport and athletic organizations[1].

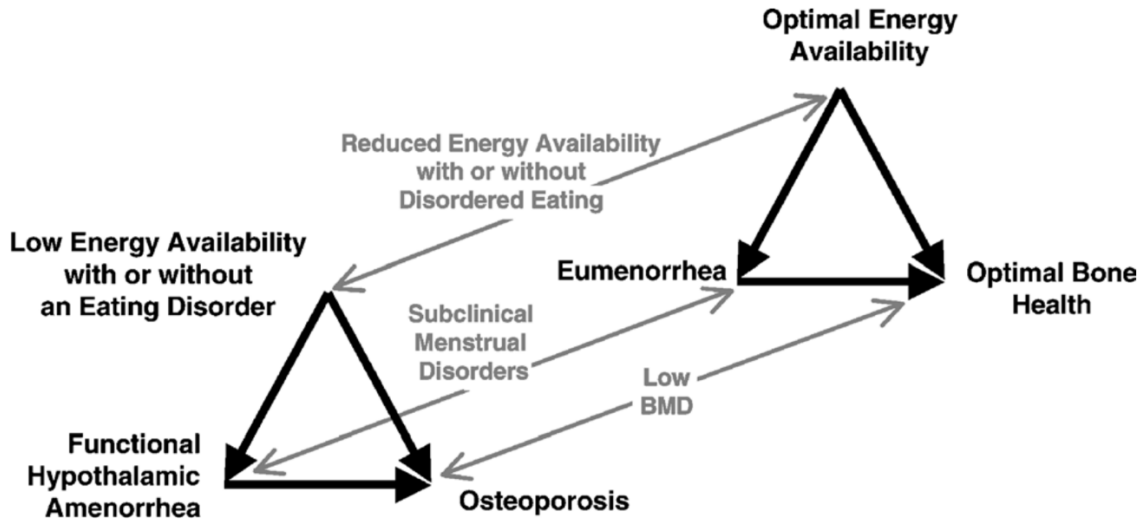

Figure 1. The Female Athlete Triad (the Triad) including spectrums of energy availability, menstrual function, and bone mineral density (from Nattiv et al., 2007)[24].

Relative Energy Deficiency in Sport (RED-S).

In 2014, the IOC published a consensus statement in efforts to update the Triad model[3]. The IOC proposed a broader, more comprehensive model known as Relative Energy Deficiency in Sport (RED-S)[3]. The RED-S model sought to address the complexities of energy deficiency, while also including male athletes, who are also affected by the physiological stresses of under fueling[3]. The condition of RED-S refers to impaired physiological function of metabolism, immunology, gastroenterology, cardiovascular system, psychology, growth and development, hematology, endocrinology, menstruation, and bone health due to low energy availability (LEA) (*refer to Figure 2)*[3]. It should be noted that the expansion to the RED-S model does not diminish the importance of the Triad and its related consequences, as the RED-S model is inclusive of the issues regarding the Triad. The cause of energy deficiency refers to an imbalance between dietary energy intake and the energy expenditure required for health and activities of daily living, including sport training[3]. The RED-S model seeks to illustrate the many aspects of physiological function, health, and athletic performance caused by relative energy deficiency[3]. Proposed performance-related consequences of RED-S include: decreased endurance, increased injury risk, decreased training response, impaired judgment, decreased coordination, decreased concentration, irritability, depression, decreased glycogen stores, and decreased muscle strength (*refer to Figure 2)*[15]. The presences of RED-S results in short-term and long-term compromise of improved health and performance in athletes[3]. Among these adverse health consequences, RED-S causes compromises in bone development, which can be irreversible. The unfavorable adaptation to bone structure, under LEA, cause increased risks of SFx[3].

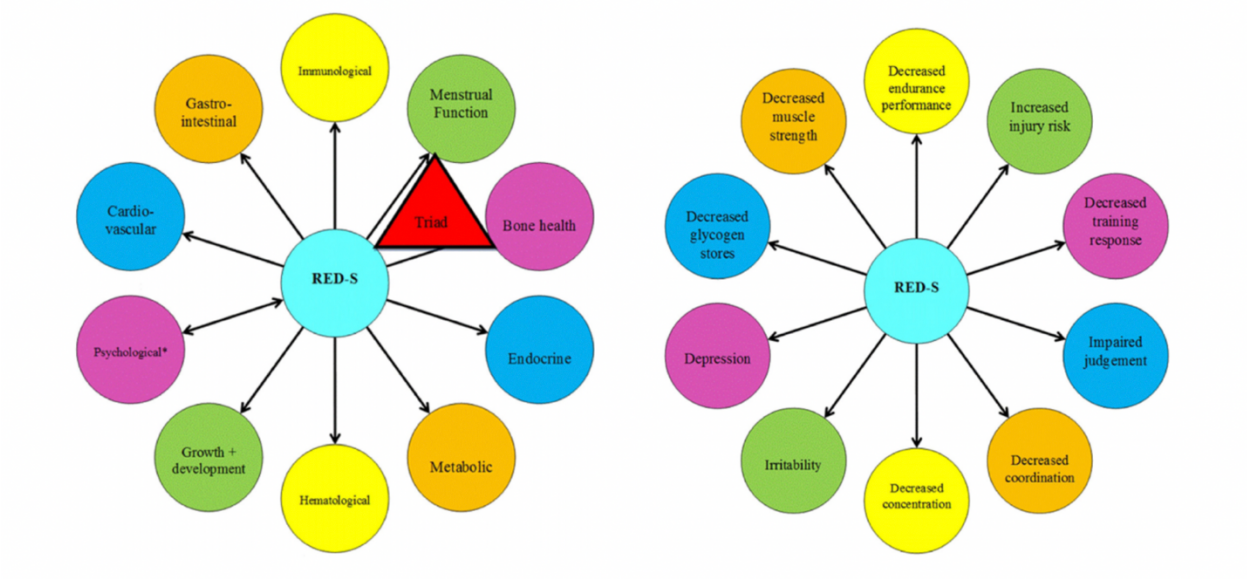

Figure 2. RED-S model: Health consequences of RED-S (left) & potential performance consequences (right), (from 2014 IOC Consensus Statement)[3].

The IOC developed a new model to assess risk for sport participation in the presence of RED-S, RED-S Clinical Assessment Tool (RED-S CAT)[26]. RED-S CAT is a clinical tool that characterizes risk stratifications based on qualifying criteria and subsequent recommendations. It is suggested that athletes in the 'High Risk' category should not be cleared for sport participation due to the serious risk participation poses to the athletes' health. High Risk criteria include serious eating disorders, other serious medical conditions (psychological or physiological) related to LEA and/or use of extreme weight loss techniques (*refer to Figure 3)*[3]. Athletes considered 'Moderate Risk' should only be cleared for sport participation under supervision and with a medical treatment plan in place[3]. Moderate Risk criteria include prolonged abnormally low percent body fat, substantial weight loss, attenuation of expected growth and development, abnormal menstrual cycle, reduced BMD, prolonged relative energy deficiency, among other criteria *(refer to Figure 3)*[3]. 'Low Risk' athletes can be cleared for full sport participation as such athletes present with healthy eating habits with appropriate EA, normal hormonal and metabolic function, a healthy BMD and musculoskeletal system *(refer to Figure 3)*[3]. RED-S risk

assessment and sport participation models have been developed to aid in clinical decision-making regarding an athletes' ability to return to sport. In the 2014 consensus statement, the IOC, similarly, provides recommendations for prevention and treatment of RED-S[3]. The primary recommendation includes education programs on RED-S and its related components, as well as evidence-based research sources, proper support and encouragement for athletes, use of a multidisciplinary team (sports physician, registered dietitian, psychologist, physiotherapist, and physiologist)[3]. The IOC calls on sport organizations at the national and international level to implement education programs for the prevention and treatment of RED-S, as well as policies for coaches in managing athlete cases[3].

High risk: no start red light	Moderate risk: caution yellow light	Low risk: green light
▶ Anorexia nervosa and other serious eating disorders ▶ Other serious medical (psychological and physiological) conditions related to low energy availability ▶ Extreme weight loss techniques leading to dehydration induced haemodynamic instability and other life-threatening conditions	▶ Prolonged abnormally low % body fat measured by DXA or anthropometry using The International Society for the Advancement of Kinanthropometry ISAK[141] or non-ISAK approaches[142] ▶ Substantial weight loss (5–10% body mass in 1 month) ▶ Attenuation of expected growth and development in adolescent athlete	▶ Healthy eating habits with appropriate energy availability
	▶ Abnormal menstrual cycle: FHA amenorrhoea >6 months ▶ Menarche >16 years ▶ Abnormal hormonal profile in men	▶ Normal hormonal and metabolic function
	▶ Reduced BMD (either from last measurement or Z-score < –1 SD). ▶ History of 1 or more stress fractures associated with hormonal/menstrual dysfunction and/or low EA	▶ Healthy BMD as expected for sport, age and ethnicity ▶ Healthy musculoskeletal system
	▶ Athletes with physical/psychological complications related to low EA/ disordered eating - ECG abnormalities- Laboratory abnormalities ▶ Prolonged relative energy deficiency ▶ Disordered eating behaviour negatively affecting other team members ▶ Lack of progress in treatment and/or non-compliance	

BMD, bone mineral density; DXA, dual-energy X-ray absorptiometry; EA, energy availability; FHA, functional hypothalamic amenorrhoea; ISAK, International Society for the Advancement of Kinanthropometry

Figure 3. RED-S risk assessment model for sport participation (from 2014 IOC Consensus Statement)[3].

In 2018, the IOC updated the consensus statement on RED-S to provide summary of the scientific progress of RED-S awareness, clinical applications, and scientific research since 2014[4]. The health effects of LEA across all identified health consequences of the RED-S model have been further examined. Researchers found that the magnitude of energy deficit, compared to baseline needs, effected the frequency of menstrual disturbances[4]. LEA also disrupts several

endocrine processes in females, like in an effort to preserve energy for essential bodily functions[4]. Hematological effects of LEA may be partially induced by, and may contribute to, iron deficiency, especially in young adult female athletes[4]. Previous research illustrates a linear growth retardation in adolescents with severe anorexia nervosa, and it is proposed that individuals with LEA may demonstrate similar physiological processes suggesting an apparent interference with growth and development that may not be irreversible[4]. Additionally, athletes with LEA may experience gastrointestinal disturbances, such as stool leakage and constipation, compared to athletes with adequate EA[4]. The updated consensus statement supports the established relationship between LEA and impaired bone health, weakened immune function, maladaptive cardiovascular changes, decreased resting metabolic rate (RMR), as well as psychological problems preceded and/or caused by LEA[4].

In the updated IOC consensus, prevention of RED-S focuses on improving awareness through mandated education programs for athletes, coaches, and other members of the sports and healthcare team[4]. Up to 2018, evidence suggests less than 50% of physicians, coaches, physiotherapists, and nurses working with athletes were able to identify the Triad components[4]. The IOC consensus recommends the development of a validated and relevant tool to screen and identify athletes at risk for RED-S, highlighting the importance for proper education of RED-S amongst athletes and the members of their team[4]. In addition, treatment and sport participation guidelines should be further developed to improve health and performance outcomes for athletes[4].

Female Endurance Athletes.

This study focuses on a particularly vulnerable population: female distance runners competing in the collegiate system, as well as the coaches and trainers who work with collegiate

female distance runners. As previously mentioned, athletes participating in sports emphasizing leanness, exhibiting increased injury risk, training for prolonged exercise bouts are at an increased risk for developing both the Triad and RED-S[24]. Among others, these risk factors are often inherent in female distance runners. This study targets female distance runners due to the high incidence of energy deficiency and disordered eating, approximately 20% reporting energy deficiency and/or disordered eating[27]. Additionally, menstrual dysfunction is common, with approximately 30% of female distance runners reporting irregularities in menstrual cycles[28,29]. Therefore, an estimated Triad or RED-S prevalence of 50-60% in distance runners helps explain the high susceptibility for developing BSI reported in this population[4,25,30,31]. These estimates are low, as athletes may withhold information out of fear of being held out of sport participation for reporting symptoms. A major consequence of distance running, especially in those suffering from the Triad and RED-S, is increased injury risk. Distance runners exhibit a higher rate of developing overuse injuries[32]. In the presence of the Triad and RED-S, such overuse injuries are compounded on top of negative consequences to bone health, which increase the risk of developing BSI. For these reasons, this study focuses on a highly susceptible population in the presence of the Triad and RED-S.

Clinical Recommendations for Screening, Treatment, and Prevention.

As previously stated, both the ACSM and IOC have recommended clinical models for the screening, treatment, and prevention of the Triad and RED-S, respectively. Both models are aimed at identifying and treating problematic symptomology, while fostering a safe and supportive environment to prevent the development of the Triad and RED-S in athletes.

Prior to the development of screening questionnaires, universities did not have evaluations in place to effectively screen for the Triad. In 2012, The Female Athlete Triad

Coalition developed a 12-item questionnaire to screen for the Triad, targeting disordered eating behaviors, menstrual dysfunction, and bone health[33]. In 2014, The Low Energy Availability among Female Athletes Questionnaires (LEAF-Q), a 25-item questionnaire, was developed to classify current EA, reproductive function, and bone health of athletes[34]. LEAF-Q aims to screen female athletes for risks of the Triad[34]. A male-centered questionnaire is in development[4]. There is currently no validated questionnaire to screen for RED-S directly, yet other questionnaires aim to screen for disordered eating and/or eating disorders in athletes. While these questionnaires have aimed to effectively screen for the Triad, it is unclear if university physicians and ATs have since required the administration of such questionnaires during the pre-participation examination (PPE) of their athletes. More than 60% of all DI universities do not require returning athletes to undergo a PPE[33]. PPE at universities should be required, minimally, prior to the beginning of every competitive season for athletes. PPEs should include questions to screen for the Triad and RED-S in both male and female athletes.

Proper treatment intervention and preventative strategies are recommended to precede and follow screening. In summary, screening tools for the Triad and RED-S should be improved to target all components of the Triad and RED-S, considering that not all athletes presenting with the Triad and RED-S will also present with disordered eating behaviors. It is important to note that athletes may be driven to hide their symptomology due to stigma or fear of being held from participation. Therefore, prioritization for the treatment and prevention of the Triad and RED-S should include, but not be limited to: 1) educational programming at all levels; 2) a multidisciplinary team; 3) policies for the management of athlete cases.

Knowledge Translation.

There is emerging attention in all areas of sports medicine supporting the importance of knowledge translation[9]. Knowledge translation, in this case, includes the creation of education programs, distribution of knowledge to athletes and staff, discussion of cases or scenarios, and an ethically-sound application of such knowledge into practice to provide more effective healthcare with respect to the Triad and RED-S[9]. Providing resources to enhance knowledge translation from evidence-based research to clinical practitioners (e.g. physicians, coaches, ATs) is necessary for the implementation of proper treatment and intervention. Knowledge translation, through educational programs, will increase the awareness, knowledge, and treatment models to manage the Triad and RED-S in athletes.

Current literature suggests that the education of the Triad and RED-S models can help decrease the risk of negative health and performance-related outcomes. Parallels can be drawn between this present study and a 2012 cross-sectional study investigating sports nutrition knowledge amongst athletes, coaches, ATs, and sports conditioning specialists[7]. Torres-McGehee et al. found that 71.4% of athletic trainers and 83.1% of conditioning staff had adequate knowledge, whereas only 35.9% coaches and 9% of athletes had adequate knowledge of sports nutrition[7]. Nutrition-related practices are prevalent and important in athletics, such that there is a call for proper nutrition programming among these staff and athletes[7].

Coaches and ATs are essential in prevention and management of these conditions due to their increased sphere of influence and daily contact with athletes[12,13,35]. Coaches are often an influential role model for athletes with heightened influence during transitional periods, such as the transition from high school to collegiate athletics[36]. Coach-athlete relationships can be positive and effective; yet it is possible for the relationship to be negative and controlling, due to

the power dynamic[36]. Because coaches hold such pivotal roles, proper education surrounding important and prevalent issues, such as the Triad and RED-S, should be required. Additionally, since ATs are often the first point of contact in an athlete's healthcare team, ATs are in a unique position to be able to observe changes in performance and/or health that could be indicative of signs/symptoms related to the Triad and RED-S[15]. While coaches and ATs should be cognizant of their scope of practice, they have a rare interpersonal relationship with athletes that allows them to recognize and intervene in the presence of performance or health-related issues[35]. Therefore, it is vital to assess the current knowledge of these populations managing athlete cases[20].

Rationale for Current Study.

Current literature has evaluated the relationship between the presence of the Triad and RED-S and negative health-related consequences, such as menstrual dysfunction and the development of BSI[1–4,11–18,31]. In addition, several studies demonstrate the effectiveness of early intervention[3,12,14,16,35] in such populations in order to reduce injury risk and health-related consequences. Yet few study designs to date (May 2020) have attempted to assess the knowledge of athletes and their support staff with respect to the Triad and RED-S *(refer to Figure 4)*. Female athletes require the proper attention in research and in clinical applications to resolve these issues. There are well-established relationships in the literature amongst the Triad and RED-S which parallel the performance and health-related consequences that are rampant in female distance running. Yet no standardized educational programs are currently in place or required to educate athletes and their support staff on these issues. Evidence-based educational programming is not only beneficial in raising awareness around these conditions but should be an institutionally mandated requirement amongst athletes and their support staff.

The primary purpose of this study is to assess the knowledge and confidence in the knowledge about the Triad and RED-S in female distance runners and their support staff, as well as the secondary effect of participant characteristics. Additionally, this study seeks to explore the current education practices that are used to increase awareness and knowledge in these populations. This study will be one of the first of its kind to explore the knowledge of female distance runners and their support staff with regards to the Triad and RED-S, such that it may uncover a large knowledge gap between the literary research and clinical application. Demonstrating such lack of knowledge will help support the call for standardized evidence-based educational programs for these athletes and their support staff.

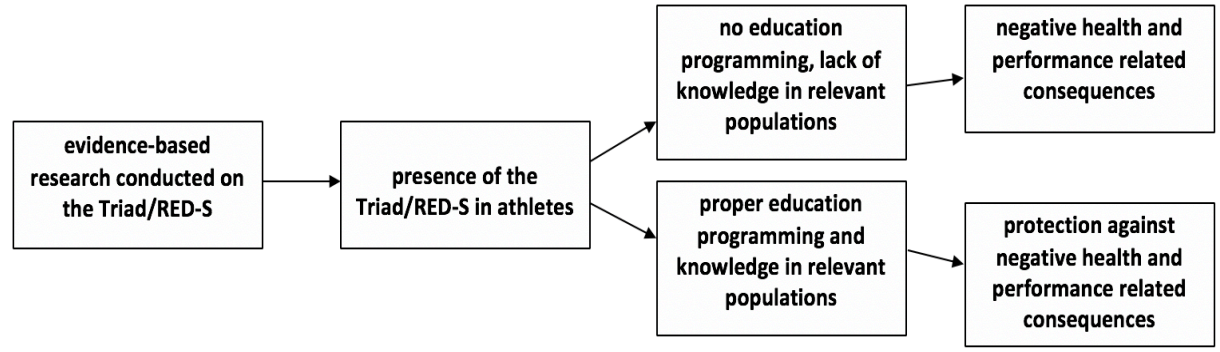

Figure 4. Theoretical model for current study: It is currently unknown whether female distance runners, coaches, and ATs have proper education and, subsequently, sufficient knowledge of the Triad and RED-S. Thus, knowledge and potential mediators of knowledge need to be examined in these populations.

Chapter III: Methods

Survey Development. An online evidence-based questionnaire served as the single instrument for the study. No identifying information was collected through the survey and answers were provided anonymously. The questionnaire aimed to assess the knowledge regarding the Triad and RED-S including questions targeting participant characteristics, knowledge, and educational training *(see: Appendix 2)*. The present questionnaire was adapted from Triad knowledge questionnaires from Frideres et al.[21]. The Triad questionnaire developed by Frideres et al. was originally tested for content validity (n = 9), instrument reliability (n = 12), and concurrent validity (n = 108)[21]. Three scores were calculated for the scored portion of the questionnaire: knowledge score, confidence score, and impact score. The impact score model was adapted from the scoring of the Triad questionnaire by Frideres et al., in which a factored, composite score of knowledge and confidence is reported (see: *Scoring* (below))[21]. The original Triad questionnaire was developed by Frideres et al. in 2015 and exclusively sought to characterize the knowledge of the Triad[21]. Primary adaptations to the current Triad and RED-S questionnaire included: 1) the inclusion of the RED-S model and additional questions/selected responses specific to RED-S, 2) assessment of three scores (knowledge, confidence, and impact scores), and 3) additional items aimed to further explore participant characteristics and educational training of participants. After adaptation, the questionnaire for this study contained 44-items for scoring and was tested for content validity and test-retest reliability. The questionnaire was validated by three content experts: 1) Medical Doctor, specializing in sports medicine and sport endocrinology; 2) Certified sports dietitian, specializing in clinical athlete care; 3) researcher specializing in female physiology and nutrition education. Content validation was obtained by three content experts who reviewed the original 'the Triad and RED-S questionnaire' for suggested changes to the

questionnaire content to better explore participant characteristics, knowledge, and education of the Triad and RED-S. The questionnaire was reduced to 38-items upon content validity testing, to better represent important knowledge questions targeted at identifying, screening, treating, and preventing the Triad and RED-S. The questionnaire was tested for test-retest reliability, reproducibility, amongst four non-collegiate female distance runners and two non-collegiate coaches of female distance runner (n =6). The 38-item questionnaire was administered via Qualtrics to reliability participants twice. Reliability participants were instructed to complete the questionnaire twice, within 48 hours, at a minimum of 1 hour apart. Reliability participants were asked to not complete any research on the Triad and RED-S between questionnaire responses. Test-retest reliability was conducted via internal consistency using the reliability coefficient, Cronbach's alpha. The validated 38-item questionnaire tested with acceptable reliability with a Cronbach's alpha of 0.799. The item with the weakest reliability correlation was removed from the questionnaire to improve the reliability, increasing Cronbach's alpha to 0.914, which is rated as excellent reliability with high internal consistency. The final version of the questionnaire used for final analysis consisted of 37-items.

Participants. Two-hundred-sixty individuals participated in this cross-sectional study: 175 collegiate female distance runners, 55 coaches of collegiate female distance runners, and 30 ATs of collegiate female distance runners. Participants were required to currently be involved in collegiate distance running via women's cross-country and track & field teams. Participants were recruited from university collegiate women's cross-country teams. Recruitment included emails to coaches and ATs, accessed through university team webpages. 440 schools across NCAA DI, DII, DIII, and NAIA programs were directly invited to participate. Coaches and ATs were asked to distribute the link to the online questionnaire to their female distance runners. Recruitment

also included the use of social media via online flyers. It is estimated that 5,280 female distance runners, 880 coaches, and 440 ATs were contacted for participation. Recruitment began March 3, 2020 and lasted until April 16, 2020. Study participation began March 3, 2020 and lasted until April 29, 2020. A flow diagram of the progress of participants through the phases of recruitment, enrollment, allocation, and analysis is included (see: Appendix 4). Online informed consent was obtained from all participants prior to participation. The Syracuse University Institutional Review Board approved this study.

Inclusion Criteria. Participants were qualified to participate in the study if they belonged to the study population groups of female collegiate distance runners, coaches of female collegiate distance runners, or ATs of female collegiate distance runners. Participants were stratified into population groups. Participants must be 18 years of age or older to participate.

Exclusion Criteria. Participants were excluded from the study if they were under the age of 18 years old. Participants were required to belong to one of the study populations: female collegiate distance runners, coaches of female collegiate distance runners, ATs of female collegiate distance runners. Participants were excluded from final analysis if they did not fully complete the scored knowledge portion of the survey. Participants who did not finish ≥ 75% of the questionnaire were removed from final analysis. Participants were also excluded from final analysis if they did not successfully select answers to confidence questions for proper scoring.

Study Design. This was a cross-sectional study examining knowledge among members within a collegiate women's cross-country team (runners, coaches, and ATs). Subjects participation included one-time completion of an online questionnaire via Qualtrics. No identifying information was collected through the survey and responses remained anonymous. The questionnaire contained sections with items targeting the following variables: participant

characteristics, a 37-item knowledge and confidence section, educational training, and exploratory variables (confidence, access, policy), as they to the Triad and RED-S.

Scoring (Knowledge, Confidence, Impact). The total knowledge score is the sum of all selected knowledge responses to all scored items of the questionnaire. One point is given for the correct answer and one point is subtracted for the incorrect answer. Therefore, the total points of total knowledge score from the questionnaire range between +37 and -37. A percentage of knowledge can be calculated using the limits of -37 to +37 of the knowledge score (range of 74 points). For questions of "choose all that apply" nature, each possible sub-answer is considered individually.

The total confidence score is the sum of all selected confidence responses to all scored items of the questionnaire. Participants self-select confidence markers from a scale of 0-4 for each knowledge question. The total confidence score is the sum of all confidence markers from each of the 37 knowledge questions. Therefore, the total points of total confidence score from the questionnaire range between 0-148. The higher the total confidence score, the more confident a participant is in their knowledge answers. The lower the total confidence score, the less confidence a participant is in their knowledge answers.

A composite score, known as the total impact score, combines knowledge and confidence from the 37 scored knowledge questionnaire items (see: Appendix 3). It is important to develop a factored composite score, which combines knowledge and confidence because it allows for greater understanding of all scores (knowledge, confidence, and impact), as well as the potential dissemination of information. For example, if a participant selects the correct knowledge answer related to the Triad and/or RED-S, but selects a low value of confidence, the participant is less likely to disseminate information based on that knowledge. However, if a participant selects the correct knowledge answer related to the Triad and/or RED-S and selects a high value of

confidence, the participant is more likely to disseminate correct information regarding the Triad and/or RED-S to other teammates, athletes, or colleagues. The total points of impact score from the questionnaire range between +37 and -37. A percentage of impact can be calculated using the limits -37 to +37 of the impact score (range of 74 points). A score of 0 will have a percentage of 50%, a score of -37 will have a percentage of 0%, and a score of +37 will have a percentage of 100%. Each question has a score range between +1 and -1. One point is given for the correct answer and high confidence and one point is subtracted for the incorrect answer and high confidence. The score of the questions is reduced when the respondent has lower confidence in their answer. The scale of confidence corresponds to the following points for impact scoring: Confidence 4 = 1 point, Confidence 3 = 0.75 points, Confidence 2 = 0.5 points, Confidence 1 = 0.25 points, Confidence 0 = 0 points. For example, if the answer is correct with the lowest confidence (1), it is scored as 0.25. If the answer is incorrect with the lowest confidence (1), it is scored as -0.25. If the answer selected if "I don't know", or a confidence of zero (0) is selected, it is scored as zero. For questions of "choose all that apply" nature, each possible sub-answer is considered individually. There are not enough data to support established reference values to indicate the level of knowledge, e.g. high/low or sufficient/insufficient knowledge. More research is warranted to establish an evaluation of the total impact score.

Scores were presented for questions specific to the Triad and questions specific to RED-S in order to assess any significant differences in knowledge, confidence and impact of these two models. Questions specific to the Triad include: 1) "The Female Athlete Triad (the Triad) consists of 3 components. Name as many as possible below" (Q16), and 2) "The three components of the Female Athlete Triad are" (Q17) (see: Appendix 2). Questions specific to RED-S include: 1) "The main cause of Relative Energy Deficiency in Sport (RED-S) is" (Q20),

2) “Select the health consequences of RED-S from the list below (select all that apply)” (Q21), and 3) “Select the performance consequences of RED-S from the list below (select all that apply)” (Q22) (see: Appendix 2). Scores for the Triad specific questions (n = 2) and RED-S specific (n = 3) were presented as percentages in order to directly compare the scores of knowledge, confidence, and impact. A percentage of the Triad specific knowledge and impact scores can be calculated using the limits of -2 to +2 of the Triad specific knowledge and impact score (range of 4 points). A percentage of the RED-S specific knowledge and impact scores can be calculated using the limits of -3 to +3 of the RED-S specific knowledge and impact score (range of 6 points).

Participant Characteristics. Participant characteristics included questions regarding mileage, total years of experience, age, sex, history of BSI, division level participation, academic area of study, Triad or RED-S diagnoses, and coaching position were collected. Mileage (mi./wk.) was collected for current mileage and peak career mileage. Mileage was defined as the number of miles run in one week, or a 7-day period. Current mileage was defined as the average miles per week the individual runs at the time the questionnaire is administered. Peak career mileage was defined as the highest number of miles the individual has ever run in one week in their lifetime. Current and peak career mileage was assessed in female distance runners and coaches to reveal significant correlations between mileage and scores of knowledge, confidence, and impact. These populations groups have a greater history of participation in distance running, whereas ATs are not often assigned to a sport in which they participated in themselves. Increased mileage is more likely to lead to LEA and/or overuse injuries, such as BSI, such that increased mileage lead to increased knowledge, confidence, and impact through outside education from physicians. Total years of experience of population groups will demonstrate how many total years a female

distance runner has been running, how many total years a coach of female distance runners has been coaching, and how many total years an AT has been practicing as an athletic trainer. Total years of experience in all population groups was analyzed to determine significant differences in scores based on total years of experience. Age was analyzed in coaches and ATs to assess differences in scores (knowledge, confidence, impact). Collegiate female distance runners have a small age range for collegiate athletic participation, such that the relationship of age and knowledge would be less generalizable. Participants will be asked about their BSI history. If a participant has experienced BSI, they will be prompted to provide a number of BSI incurred (BSI prevalence); if a participant has not experienced BSI, BSI will be reported as 0. Total BSI includes all participants BSI history, including those reporting 0. BSI prevalence includes participants with 1 or more BSI. BSI was analyzed in female distance runners and coaches, as the measure of BSI due to overuse in running, specifically, is most relevant to these population groups. Division level participation includes NCAA DI, NCAA DII, NCAA DIII, and NAIA. Division level participation was analyzed across all population groups to explore if increased resources and funds at NCAA DI may contribute to increased awareness and knowledge, confidence, and impact. Participants were asked to provide their highest degree completed, along with their major area of study and year of completion. Academic area of study was assessed as related or unrelated to the Triad and RED-S. Related academic area of study include degrees related to health and performance, such as exercise science, kinesiology, biology, physiology, pre-medical studies, nutrition, dietetics, health studies, athletic training, physical therapy, chiropractic, and nursing. Unrelated academic area of study is defined as any degree that is not included in related academic area of study, such as business, communications, marketing, journalism, and several others. Academic area of study was analyzed in female distance runners

and coaches, as ATs all have education requirements under the related academic area of study. Coaches and athletes do not have educational degree requirements for their academic area of study, such that it is important to assess whether scores significantly differ between groups. Participants were asked if they had ever been diagnosed with the Triad or any of its' components or RED-S or any of its' components. Participants who indicated yes to either Triad or RED-S, will be grouped as positive diagnosis for Triad or RED-S, respectively. Triad and RED-S diagnoses were analyzed to examine differences in scores amongst female distance runners. Coaches were asked about their current coaching position including head coach, assistant coach, graduate assistant coach, or student (undergraduate) assistant coach. Coaching position was analyzed to examine differences in knowledge, due to the management of roles and duties amongst coaching staff members. All scores (knowledge, confidence, and impact) will be examined against participant characteristics, in order to reveal any significant relationships between knowledge, confidence, or impact and participant characteristics. Univariate GLM was used to explore significant interaction(s) between division level participation and peak career mileage, as well as peak career mileage and Triad diagnosis amongst female distance runners. Impact scores of DI female distance runners (mean score of 19.98 ± 7.05) significantly differed from the impact scores of non-DI female distance runners (mean score of 17.36 ± 6.82) ($p < 0.05$; Table 5); and there was a weak, significant correlation between impact score and peak career mileage. Therefore, the interaction of division level participation and peak career mileage was explored to uncover which variable was driving the significant differences in impact scores. Furthermore, impact scores significantly differed in female distance runners with a positive Triad diagnosis (26.52 ± 5.05 and 21.69 ± 5.85, respectively) compared to female distance runners with a negative Triad diagnosis (23.84 ± 4.92 and 16.80 ± 6.54, respectively) ($p < 0.01$; Table 7);

in which case the interaction of Triad diagnosis and peak career mileage was assessed to reveal the relationship to impact score when taken together.

Education. Current and continuing education of all population groups were collected, both generally and specific to the Triad and RED-S. University athletic departments have education programs or training in place for the athletes, coaches, and staff members. Participants were asked about their exposure to general educational training from their athletic departments and educational training specific to the Triad and RED-S. Independent samples T-tests were used to assess differences in knowledge in those who received educational programming related to the Triad and RED-S from their athletic department versus those who did not receive educational training. Participants were also asked about educational training related to the Triad and RED-S, that may or may not have been provided by their athletic departments. Participants may seek out educational training related to the Triad and RED-S that is not affiliated with the university. Training on the Triad and RED-S, as collective entities, were assessed using independent samples T-tests to examine differences in knowledge in those who received educational training on the Triad or RED-S as collective entities versus those who did not receive educational training on the Triad or RED-S as collective entities.

Exploratory Variables. Exploratory questions will be asked at the end of the survey in order to further understand confidence, policies, and access as it relates to the Triad and RED-S and the proper intervention and treatment of athletes. Knowledge translation from coaches and ATs to the female distance runners was sampled from female distance runners. Female distance runners were asked whether or not their coaching staff or ATs provided information regarding the Triad and RED-S to them or their teammates. All participants were sampled on the resources they most desired to increase education of the Triad and RED-S. Participants were also surveyed on the

types of education programs they would most likely participate in; shall education programs be available and offered. These variables will also help inform next steps in educational programs, institutional practices, and future research.

Statistical Analyses. All variables were tested for non-normality using Shapiro-Wilk test and Kolmogorov-Smirnov test for normality, before statistical hypothesis tests were performed. Participant characteristics were analyzed using descriptive statistics and are presented in Table 1. Total knowledge, confidence, and impact scores between population groups were analyzed using a one-way ANOVA; a Tukey Post Hoc Analysis was performed in the presence of a significant main effect. Triad specific knowledge and impact scores as well as RED-S specific knowledge and impact scores between population groups were analyzed using a one-way ANOVA; a Tukey Post Hoc Analysis was performed in the presence of a significant main effect. Paired samples T-tests were used to assess significant differences in Triad specific knowledge and RED-S specific knowledge, as well as Triad specific impact and RED-S specific impact within population groups. Scores (knowledge, confidence, and impact) assessed by categorical variables were analyzed using independent samples T-test. Independent samples T-tests were performed between knowledge and the following variables (note that the parentheses indicate the population groups the tests were performed within); division participation level (all population groups), academic area of study (runners and coaches), sex (coaches and ATs), Triad and RED-S diagnosis (runners), and coaching position (coaches). Data for continuous variables were analyzed using Pearson's correlations and Spearman's correlations. Pearson's bivariate correlations were performed between scores and the following variables: peak career mileage (runners and coaches), total years of experience (runners and coaches), and age (coaches), as these variables were normally distributed. Spearman's correlations were performed between

knowledge and the following variables: current mileage (runners), BSI incidence (runners and coaches), age (ATs), and total years of experience (ATs), as to control for these variables that expressed skewness. Univariate General Linear Model (GLM) was used to assess impact scores in a multivariate approach. Univariate GLM indicates significant interaction(s) between the following variables: division level participation and peak career mileage, as well as peak career mileage and Triad diagnosis amongst female distance runners. A significance level was set at $p \leq 0.05$ *a priori.* All data were presented as means ± standard deviation. IBM Statistical Package for the Social Sciences (SPSS) was used for data analysis.

Chapter IV: Results

Participant Characteristics. Participants descriptive characteristics are shown in Table 1. Participants frequency descriptive characteristics are shown in Table 2. Participants were recruited via email and social media for participation; coaches and ATs from 440 colleges and universities were contacted directly for participation (n = approx. 6600 participants). 341 participants enrolled in the questionnaire and were assessed for eligibility. Upon assessment of inclusion and exclusion criteria, 260 participants were included in the final analysis: 175 female distance runners, 55 coaches of female distance runners (29 males; 26 females), and 30 ATs of female distance runners (26 females; 3 males). The estimated response rate was approximately 5.1% and the experimental mortality rate was 23.7%. Flow diagram of the progress of participants through the phases of recruitment, enrollment, allocation, and analysis are shown in Appendix 4. Participants belonged to NCAA DI (n = 140), NCAA DII (n = 38), NCAA DIII (n = 63) and NAIA (n =19) institutions, however relationships were examined in NCAA DI institutions versus non-DI institutions with respect to total impact scores. Due to the small sample size and relative distribution of resources and funds; DII, DIII and NAIA institutions were combined to form participants at non-DI institutions. Coaching positions included head coaches (n = 23), assistant coaches (n = 27) and graduate assistant coaches (n = 5). In the final analysis coaching positions were examined with respect to knowledge in head coaches versus assistant coaches. Assistant coaches and graduate assistant coaches were combined to form the assistant coaches' group, due to the small sample size of graduate assistant coaches and the similar roles of assistant coaches. As expressed in post-hoc differences of a one-way ANOVA, total knowledge score, calculated from the Triad and RED-S questionnaire, were significantly different in female distance runners compared to coaches (mean knowledge scores of 25.00 ±

5.27 and 26.92 ± 5.02, respectively), as well as significantly different in female distance runners compared to ATs (mean knowledge score of 28.66 ± 4.02) ($p < 0.05$; Table 1). Total confidence scores were significantly different in female distance runners compared to coaches (mean confidence scores of 95.42 ± 28.83 and 111.35 ± 24.14, respectively), as well as significantly different in female distance runners compared to ATs (mean confidence score of 117.67 ± 22.53) ($p < 0.05$; Table 1). Total impact scores were significantly different in female distance runners compared to coaches (mean scores of 18.81 ± 7.05 and 22.41± 6.33 respectively), as well as significantly different in female distance runners compared to ATs (mean scores of 18.81 ± 7.05 and 23.93 ± 5.69, respectively) ($p < 0.05$; Table 1). No scores of knowledge, confidence, and impact were significantly different between coaches and ATs ($p > 0.05$; Table 1).

Assessment of Knowledge, Confidence, & Impact. In this cross-sectional design, total impact score was calculated from 37-items surveying knowledge and confidence from the Triad and RED-S questionnaire. Therefore, total impact scores had a range of -37 to +37. Female distance runners (n = 175) had the lowest mean knowledge, confidence, and impact scores of 25.00 ± 5.27, 95.42 ± 28.83, and 18.81 ± 7.05. Coaches of female distance runners (n = 55) had mean knowledge, confidence, and impact scores of 26.92 ± 5.02, 111.35 ± 24.14, and 22.41 ± 6.33, respectively. ATs of female distance runners (n = 30) demonstrated the highest mean knowledge, confidence, and impact scores of 28.66 ± 4.02, 117.67 ± 22.53, and 23.93 ± 5.69, respectively. According to post-hoc differences in a one-way ANOVA, total knowledge, confidence and impact scores significantly differed between female distance runners (mean scores of 25.00 ± 5.27, 95.42 ± 28.83, and 18.81 ± 7.05, respectively) and coaches (mean scores of 26.92 ± 5.02, 111.35 ± 24.14, and 22.41 ± 6.33, respectively), ($p < 0.05$; Table 1). According to post-hoc differences in a one-way ANOVA, total knowledge, confidence, and impact scores significantly

differed between female distance runners and ATs (mean scores of 26.92 ± 5.02, 111.35 ± 24.14, and 22.41 ± 6.33, respectively), ($p < 0.05$; Table 1). No significant differences in total knowledge, confidence, or impact scores were revealed between coaches and ATs ($p > 0.05$; Table 1).

There are no established reference values of total knowledge or impact scores to indicate the level of knowledge by groups of high to low or sufficient versus insufficient knowledge. However, a percentage can be calculated using the limits of -37 to +37 of the score for both knowledge and impact (range of 74 points). Female distance runners had a mean knowledge and impact score, expressed as percentages, of 83.7% and 75.4% respectively. Coaches had a mean knowledge and impact score, expressed as percentages, of 86.4% and 80.3% respectively. ATs had a mean knowledge and impact score, expressed as percentages, of 88.7% and 82.3% respectively.

The Triad specific knowledge (%) was 57.48 ± 28.7 in female distance runners, 66.70 ± 30.25 in coaches, and 77.14 ± 22.0 in ATs. The Triad specific impact (%) was 58.45 ± 21.65 in female distance runners, 68.06 ± 26.24 in coaches, and 75.68 ± 21.03 in ATs. The RED-S specific knowledge (%) was 70.52 ± 17.58 in female distance runners, 70.93 ± 17.85 in coaches, and 79.80 ± 17.43 in ATs. The RED-S specific impact (%) was 61.41 ± 12.72 in female distance runners, 63.93 ± 15.07 in coaches, and 70.66 ± 14.15 in ATs. According to post-hoc differences in a one-way ANOVA, Triad specific knowledge, Triad specific impact, RED-S specific knowledge, and RED-S specific impact significantly differed between female distance runners and ATs ($p < 0.05$; Table 1). According to post-hoc differences in a one-way ANOVA, Triad specific impact significantly differed between female distance runners (58.45 ± 21.65) and coaches (68.06 ± 26.24) ($p < 0.05$; Table 1). The mean differences, according to paired T-tests,

between Triad specific knowledge and RED-S specific knowledge, in female distance runners, was -13.04 ± 29.62 ($p < 0.001$; Table 1). The mean differences between Triad specific impact and RED-S specific impact, in female distance runners, was -2.96 ± 19.91 ($p > 0.05$; Table 1). In coaches, the mean differences between Triad specific knowledge and RED-S specific knowledge was -4.23 ± 30.97 and the mean differences between Triad specific impact and RED-S specific impact was 4.13 ± 25.95 ($p > 0.05$; Table 1). In ATs, the mean differences between Triad specific knowledge and RED-S specific knowledge was -2.66 ± 27.14 and the mean differences between Triad specific impact and RED-S specific impact was 5.02 ± 25.61 ($p > 0.05$; Table 1).

Examination of Potential Mechanisms of Scores (Knowledge, Confidence, Impact). Pearson's bivariate correlations between total knowledge and impact score and peak career mileage (in runners and coaches), total years of experience (in runners and coaches), and age (in coaches) were performed to determine associations between participant characteristic variables and their effect on knowledge and impact scores. Spearman's correlations between total impact score and current mileage (in runners), BSI prevalence (in runners and coaches), age (in ATs), and total years of experience (in ATs) were also performed to determine significant differences between participant characteristics and impact scores. Independent samples T-tests between total knowledge, confidence, and impact scores and division level participation (in all populations), academic area of study (in runners and coaches), sex (in coaches and ATs), and coaching position (in coaches) were performed to determine significant differences in population groups.

In female distance runners, a weak, but significant, correlation was found between knowledge and impact scores and peak career mileage ($r = 0.173$ and 0.195 respectively, $p < 0.05$; Table 3). The association between mean impact score and peak career mileage is represented in a scatterplot in Figure 1. Knowledge scores of DI female distance runners (mean

score of 26.03 ± 5.33) significantly differed from the knowledge scores of non-DI female distance runners (mean score of 23.73 ± 4.93) ($p < 0.05$; Table 5). Impact scores of DI female distance runners (mean score of 19.98 ± 7.05) significantly differed from the impact scores of non-DI female distance runners (mean score of 17.36 ± 6.82) ($p < 0.05$; Table 5). Knowledge, confidence, and impact scores significantly differed among female distance runners with a related academic area of study (e.g. exercise science, kinesiology) versus female distance runners with an unrelated academic area of study (e.g. business, communications). Female distance runners with a related academic area of study ($n = 27$) had a mean knowledge score 26.60 ± 4.00, whereas female distance runners with an unrelated academic area of study ($n = 35$) had a mean knowledge score of 22.70 ± 5.42 ($p < 0.05$; Table 6). Female distance runners with a related academic area of study had a mean confidence and impact score of 108.19 ± 19.44 and 21.91 ± 5.16 respectively ($p < 0.01$; Table 6). Whereas female distance runners with an unrelated academic area of study had a mean confidence and impact score of 87.77 ± 23.27 and 16.11 ± 5.54 respectively ($p < 0.01$; Table 6). Knowledge and impact scores significantly differed in female distance runners with a positive Triad diagnosis (26.52 ± 5.05 and 21.69 ± 5.85, respectively) compared to female distance runners with a negative Triad diagnosis (23.84 ± 4.92 and 16.80 ± 6.54, respectively) ($p < 0.01$; Table 7). Knowledge and impact scores significantly differed in female distance runners with a positive RED-S diagnosis (27.34 ± 5.30 and 22.58 ± 6.82, respectively) compared to female distance runners with a negative RED-S diagnosis (23.91 ± 4.96 and 17.20 ± 6.34, respectively) ($p < 0.01$; Table 8). In female distance runners, no significant correlations were found between impact scores and the following variables assessed: current mileage (Table 4), total BSI (Table 4), BSI prevalence (Table 4), and total years of experience (Table 3) ($p > 0.05$).

In coaches of collegiate female distance runners, confidence and impact scores significantly differed between coaches at NCAA DI institutions and coaches at non-DI institutions. DI coaches ($n = 30$) had a mean confidence and impact score of 119.37 ± 15.72 and 24.13 ± 4.57, respectively. Whereas non-DI coaches ($n = 25$) had a mean confidence and impact score of 101.72 ± 28.90 and 20.35 ± 7.55 ($p < 0.05$; Table 14). Knowledge scores did not significantly differ between coaches at NCAA DI institutions and coaches at non-DI institutions ($p > 0.05$; Table 14). In coaches of collegiate female distance runners, no significant correlations were found between impact scores and the following variables assessed: total BSI (Table 10), BSI prevalence (Table 10), total years of experience (Table 9), age (Table 9), and peak career mileage (Table 9) ($p > 0.05$). No significant differences were found between knowledge, confidence, and impact scores the following variables assessed: sex (Table 11), academic area of study (Table 12), and coaching position (Table 13) ($p > 0.05$).

In ATs of collegiate female distance runners, no significant correlations were found between knowledge and impact scores and the following variables assessed: total years of experience and age ($p > 0.05$; Table 15). No significant differences were found between knowledge, confidence, and impact scores and the following variables assessed: sex (Table 16) and division participation (Table 17) ($p > 0.05$).

Furthermore, multivariate analyses illustrate a non-significant interaction between peak career mileage and division level participation in female distance runners ($p > 0.05$; Table 18; Figure 7). There is no significant effect of division level participation on impact scores after controlling for peak career mileage. Such that, the significant difference in DI participants vs. non-DI participants previously explored ($p < 0.05$; Table 5) is no longer significant once peak career mileage is taken into account. The univariate GLM illustrates a borderline significant

main effect of mileage ($p = 0.087$; Table 18; Figure 7). There was a significant interaction between peak career mileage and Triad diagnosis in female distance runners, $F(1, 156) = 8.309$, $p = 0.005$ (Table 18; Figure 8). There is a significant main effect of Triad diagnosis ($p < 0.001$) and peak career mileage ($p < 0.05$) (Table 18). Therefore, in this interaction, the effect of Triad diagnosis depends on peak career mileage (Figure 8).

Characterization of Education. Participants were asked about the previous and current exposure to educational programming. When surveyed about educational programming from athletic departments, 69.32% of female distance runners, 52.63% of coaches, and 51.61% of ATs indicated not receiving educational programming about the Triad and RED-S from their athletic departments (Figure 2). At their current institutions, 84.21% of female distance runners, 89.29% of coaches, and 70.97% of ATs indicated having not received training or educational programming regarding the Triad and/or RED-S (Figure 3). Individuals who indicated they had received training regarding the Triad and/or RED-S, indicate that disordered eating and eating disorders were the primary, or only, component of education. Participants were asked about the exposure to training on the Triad and RED-S as collective entities, in any setting or capacity. Greater than 50% of female distance runners and coaches had not received any training on the Triad or RED-S as a collective entity, however ATs expressed a greater degree of training. Overall, few participants had received training on RED-S compared to training on the Triad. 67.82% of female distance runners indicated they had not received training on the Triad as a collective entity and 77.59% of female distance runners indicated they had not received training on RED-S as a collective entity (Figure 4). 64.91% of coaches indicated they had not received training on the Triad as a collective entity and 70.18% of coaches indicated they had not received training on RED-S as a collective entity (Figure 4). 12.9% of ATs indicated they had not

received training on the Triad as a collective entity and 40.0% of ATs indicated they had not received training on RED-S as a collective entity (Figure 4). Female distance runners were asked if their coaching staff or ATs personally provide information to themselves and teammates about the Triad and RED-S. 78.9% indicated their coaches did not and 80.0% indicated their ATs did not (Figure 5).

Impact scores significantly differed, via independent samples T-tests, in female distance runners who received Triad training as a collective entity (mean impact score of 21.03 ± 6.86) compared to female distance runners who did not receive Triad training as a collective entity (mean impact score of 18.12 ± 6.82) ($p < 0.05$; Figure 4). However, impact scores did not significantly differ in individuals who received RED-S training as a collective entity compared to those who did not ($p > 0.05$; Figure 4). Impact scores significantly differed, via independent samples T-tests, in coaches that received Triad training as a collective entity (mean impact score of 25.10 ± 4.50) compared to coaches that did not receive Triad training as a collective entity (mean impact score of 20.10 ± 6.75) ($p < 0.05$; Figure 4). Impact scores significantly differed in coaches who received RED-S training as a collective entity (mean score of 25.81 ± 4.41) compared to coaches who did not receive RED-S training (mean score of 21.06 ± 6.52) ($p < 0.01$; Figure 4). No impact scores were associated with any training regarding the Triad or RED-S as a collective entity in ATs ($p > 0.05$; Figure 4). According to independent samples T-tests, no impact scores significantly differed among those who received educational programming provided by the athletic department regarding the Triad and/or RED-S and those who did not receive such educational programming, across all study population groups ($p > 0.05$; Figure 2). Participants were asked to select all types of general continuing education they take part in at least once a year ($n = 252$). Female distance runners indicated they received general continuing

education, primarily, in the form(s) of athletic department programs (20.35%), searching/reading information online (20.13%), and NCAA-sponsored programs (15.10%) (Figure 6). Coaches indicated they received general continuing education, primarily in the form(s) of reading textbooks related to coaching, physiology, nutrition, etc. (15.89%) and attending professional conferences (15.50%) (Figure 6). ATs indicated they received general continuing education, primarily, in the form(s) of attending professional conferences (18.24%), consulting professionals (e.g. sports physician, registered dietitian, etc.) (15.54%), and reviewing professional journals (15.54%) (Figure 6).

Participants were asked to select all types of Triad and/or RED-S specific continuing education they take part in at least once a year (n = 247). Female distance runners indicated they received Triad and/or RED-S continuing education, primarily, in the form(s) of not participating in any continuing education (23.90%) and search/read information online (22.06%) (Figure 6). Coaches indicated they received Triad and/or RED-S continuing education, primarily, in the form(s) of not participating in any continuing education (16.67%), reading textbooks related to coaching, physiology, nutrition, etc. (15.00%), and reviewing professional journals (14.17%) (Figure 6). ATs indicated they received Triad and/or RED-S continuing education, primarily, in the form(s) of consulting professionals (e.g. sports physician, registered dietitian, etc.) (20.25%), attending professional conferences (18.99%), and reviewing professional journals (17.72%) (Figure 6). While, 8.86% of ATs indicated they did not participate in any continuing education with respect to the Triad and/or RED-S. Despite these findings, a majority of participants expressed interest attending educational training with respect to the Triad and RED-S, if their institution offered training. By population, 81.50% of female distance runners, 94.74% of coaches, and 100% of ATs indicated they would attend educational training. Participants who

expressed interest in attending educational training (n = 226) cited the primary reasons they would attend were as follows: 1) to increase knowledge and awareness of the Triad and RED-S, and 2) be a better member of their team and improve the health of athletes. For participants who did not express interest in attending educational training (n = 35), the primary reasons for not attending were as follows: 1) associated costs (e.g. money, time), and 2) potential trigger for sufferers.

Exploratory Aims. Additional exploratory variables were collected via questionnaire items to provide further understanding and/or more informed steps for future direction(s). These exploratory aims reveal concerns related to the Triad and RED-S surrounding confidence, policy, and access at the individual and institutional level.

Female distance runners were sampled regarding their confidence when they or a teammate presents with identifying and reporting symptoms of the Triad and RED-S. When asked whether they would feel confident identifying the Triad and RED-S if they present with symptoms, 53.7% of female distance runners indicated they would feel confident. However, only 48.5% of female distance runners indicated they would feel confident to self-report their symptoms to a coach or AT. Yet, >60% indicated they would seek outside help from a physician, registered dietitian, or psychologist if they presented with the Triad and/or RED-S. Only 33.33% of female distance runners believed their coaching staff has a good understanding of the Triad and/or RED-S and 39.66% of female distance runners believed their AT has a good understanding of the Triad and/or RED-S.

Female distance runners were sampled regarding policy in their athletic departments or on their teams. When asked if their athletic department ‘currently has a policy in place that specifies what to do when I suspect that I or a teammate may be suffering from one or more

aspects of the Triad and/or RED-S' (see: Appendix 2, Q60), only 3.9% of female distance runners indicated that their athletic department has such a policy. 51.1% indicated their athletic departments do not have a policy in place and 44.9% were unsure. When asked if their coaching staff has a policy for their team (see: Appendix 2, Q61), 6.8% of female distance runner participants indicated their coaching staff has such a policy. Therefore, 58% indicated their coaching staff do not have a policy in place and 35.2% did not know.

As previously explored in related mechanisms to knowledge and impact, access to adequate resources, funds, and appropriate medical professionals are issues faced across collegiate institutions. Impact scores significantly differed among NCAA DI participants compared to non-DI participants ($p < 0.05$), in female distance runners. Impact scores also significantly differed between NCAA DI coaches and non-DI coaches ($p < 0.05$). Female distance runners participating in NCAA DI programs had the greatest access to certified sports dietitian(s) (63.16%). In comparison, 31.14% of NCAA DII participants, 14.63% of NCAA DIII, and 0.00% of NAIA participants indicated having access to certified sports dietitian(s). Female distance runners participating in NAIA programs had the least access to mental health specialist(s) (66.67%). In comparison, 87.80% of NCAA DIII, 82.14% of NCAA DII, and 81.06% of NCAA DI participants indicated having access to a mental health specialist.

Chapter V: Discussion

Using a cross-sectional study design, we examined the knowledge, confidence, and impact of the Triad and RED-S in collegiate female distance runners, coaches of collegiate female distance runners, and ATs of collegiate female distance runners. In summary, ATs demonstrated the highest knowledge, confidence, and impact scores and female distance runners demonstrated the lowest knowledge, confidence, and impact scores on the 37-item scored portion of the Triad and RED-S questionnaire. Coaches' scores (knowledge, confidence, and impact) were significantly different from the female distance runners', but not from the ATs'. Female distance runners' knowledge, confidence, and impact scores were significantly different from the impact scores of coaches and ATs ($p < 0.05$). In addition, ATs' Triad specific knowledge and impact, as well as RED-S specific knowledge and impact were significantly different from the female distance runners', but not from the coaches. Coaches' Triad specific impact was significantly different from the female distance runners. Due to the significant difference in scores (knowledge, confidence, and impact) of the coaches and ATs compared to female distance runners, coaches and ATs demonstrate an ability to help increase awareness and knowledge in female distance runners. Coaches and ATs are more likely to belong to professional groups and attend professional conferences where their exposure to education of the Triad and RED-S may be increased. However, student athletes often rely on educational programming provided by their athletic departments or their formal education through their academic area of study. Due to the lack of education and mandated training at the athletic department level, student athletes (in this case, collegiate female distance runners) are potentially at the greatest risk for a lack of education. This may be supported by the significantly lower scores in female distance runners. It was hypothesized that participants would score higher on Triad specific questions compared to

RED-S specific questions because the development and research of the Triad model was proposed in 1992 compared to the RED-S model which was proposed in 2014. However, female distance runners scored higher on RED-S specific knowledge compared to Triad specific knowledge ($p < 0.05$). There was no significant difference in Triad specific impact scores and RED-S specific impact scores amongst female distance runners. These relationships should be further assessed across Triad and RED-S knowledge and impact scores, with a greater number of specific Triad and RED-S questions to explore the differences in knowledge, confidence, and impact of the Triad versus RED-S.

Scores of knowledge, confidence, and impact differed most significantly amongst female distance runner characteristics. Female distance runners who expressed higher peak career mileage, a related academic area of study, NCAA DI participation, and positive Triad and RED-S diagnoses demonstrated higher knowledge and impact scores ($p < 0.05$). Knowledge and impact scores of coaches significantly differed between division level participation, such that coaches with NCAA DI participation demonstrated higher knowledge and impact scores ($p < 0.05$). NCAA DI participants demonstrated higher knowledge and impact scores in female distance runners and coaches ($p < 0.05$), such that awareness, education, resources, and policies should continue to be assessed across division level participation. One potential contributing factor to the significant difference in knowledge and impact scores in NCAA DI institutions vs. non-DI institutions is the greater access to certified sports dietitians at NCAA DI institutions. As LEA is a major contributing factor to the development of the Triad and RED-S, certified sports dietitians on staff are vital professionals to assess the clinical needs of athletes, such as their energy availability. Knowledge and impact scores of female distance runners significantly differed between Triad and RED-S diagnoses. Female distance runners with positive Triad and

RED-S diagnoses demonstrated higher knowledge, confidence, and impact scores ($p < 0.01$). A potential contributing factor to the significant difference in female distance runners with positive Triad and RED-S diagnoses versus those with negative Triad and RED-S diagnoses is the exposure to formal diagnoses by medical professionals and/or education of the Triad and RED-S from their medical professional. This is important to consider in the education for the prevention of the Triad and RED-S.

In the univariate analysis model, DI participants had a mean impact score of 19.98 ± 7.05 versus non-DI participants who had a mean impact score of 17.35 ± 6.82 (Table 5), and there was a weak, but significant, correlation between peak career mileage and impact scores ($r = 0.195$; $p = 0.010$; Table 3; Figure 1). These group differences can be further explained by the multivariate analysis which illustrated a weak, nearly significant association between peak career mileage and impact scores ($p = 0.087$; Table 18; Figure 7). The significant differences in impact scores of DI participants versus non-DI participants, as assessed through independent samples T-tests, does not remain significant when controlling for peak career mileage. Therefore, it is less likely to be explained by greater access to resources/funds at the DI level. Rather, it more likely to be attributed to the weak association of higher peak career mileage, which is driving the overall difference in impact scores. This suggests that female distance runners at the DI level are more likely to have a higher peak career mileage. Furthermore, multivariate analysis also illustrated there was a significant interaction between peak career mileage and Triad diagnosis in female distance runners, $F (1, 156) = 8.309$, $p = 0.005$ (Table 18; Figure 8). Such that, a positive Triad diagnosis in female distance runners depends on peak career mileage. Female distance runners with higher peak career mileage are at a greater risk of LEA, due to their high energy expenditure from higher mileage. Individuals with a greater risk of LEA are consequently at a

greater risk for developing the Triad and its' related symptoms (e.g. bone stress injuries, menstrual irregularities), as evidenced by higher incidences of BSI with single and combined risk factors of the Triad[5]. This is also supported by literature suggesting LEA is a strong predictor of developing the Triad and consequently its' validity as a screening tool for the Triad[3,34]. Additionally, female distance runners presenting with the Triad and its' related symptoms are more likely to see a physician and/or RD, in which case the individual would become educated on the Triad and its' consequences, as well as the treatment and prevention of the Triad. These relationships are extremely important to consider in the context of our present study, such that female distance runners are likely not receiving information or education on the Triad and its' consequences until the individual is presenting with the Triad. However, if female distance runners are properly educated on the health and performance consequences associated with the Triad and RED-S, they may be more likely to seek help from coaches, ATs, or other medical health professionals at the proper time. Proper educational training should be implemented in order to increase knowledge of the Triad and RED-S amongst female distance runners prior to the athlete presenting with the Triad and/or RED-S.

There is currently a lack of educational training received by all population groups as it directly relates to the Triad and RED-S. A majority of participants across all population groups do not receive continuing education from their current institutions with respect to the Triad and/or RED-S (84.21% of female distance runners, 89.29% of coaches, and 70.97% of ATs indicate not receiving educational training through their current institution). Educational training on RED-S is less common than educational training on the Triad. 67.82% of female distance runners and 64.91% of coaches reported not receiving training on the Triad as a collective entity.

Additionally, 77.59% of female distance runners, 70.81% of coaches, and 40.00% of ATs reported not receiving training on RED-S as a collective entity.

Impact scores of female distance runners and coaches of female distance runners who received Triad training were significantly different than those who did not receive Triad training. Participants were more likely to receive training on the Triad than RED-S. However, while a more recently defined concept, RED-S is the more inclusive model concerned with identifying several other health and performance implications regarding LEA. Consequently, athletes, coaches, and all members of the sporting and healthcare teams are likely overlooking the further implications of RED-S. By focusing on the Triad, individuals may not properly identify or report a number of other signs and symptoms related to RED-S, but not the Triad.

This study suggests that participant characteristics have little effect on total impact scores. However, relationships that did indicate significant differences were often revealed in education-based relationships, such as academic area of study in female distance runners, Triad training in coaches and female distance runners, and RED-S training in coaches. These findings further support the importance of educational training, which should be a primary method to significantly increase knowledge of the Triad and RED-S across all population groups in order to improve the prevention and treatment of the Triad and RED-S. In addition, significant differences revealed in female distance runners with positive Triad and RED-S diagnoses underscore the importance of education in the prevention and management of the Triad and RED-S.

No evidence-based education programs currently exist in collegiate athletic departments with respect to the Triad and RED-S. Therefore, the educational resources that universities may or may not be providing, such as pamphlets and academic journal articles, to their athletes and

staff members are not associated with increased impact scores. A potential explanation for this lack of increased knowledge in the presence of educational resources is that athletes and staff members are not required to engage with the educational materials. They may not engage with the material or understand the information or further implications the Triad and RED-S has on their teams. An alternative mechanism to the current educational resources that may or may not be provided is mandatory educational training for all athletes and staff members. Future educational training should focus on the inclusion of both the Triad and RED-S and emphasize the importance of all related symptoms, as well as the health and performance consequences.

Through the investigation of additional exploratory variables, understanding of the study's primary findings may be explained. These exploratory aims disclose concerns related to the Triad and RED-S with respect to confidence, policy and access. Fewer female distance runners reported feeling confident self-reporting symptoms to their coaches and ATs (48.50%), than felt confidence identifying such symptoms if they presented with them (53.70%). These figures suggest that female distance runners lack confidence in their support staff, coaches and ATs, and in their ability to address issues surrounding the Triad and/or RED-S. Potential explanations of this lack of confidence may include, but are not limited to: fear of being held out of sport, distrust in the proper receival of care from support staff, and uncertainty in reporting symptoms. Furthermore, only 33.33% female distance runners believe their coaching staff has a good understanding of the Triad and RED-S and only 39.66% of female distance runner believe their ATs have a good understanding of the Triad and/or RED-S. This lack of confidence in their support staff may be explained by an inability to address concerns in athletes and a lack of intervention by staff, as demonstrated by a lack of education or established policies by coaches and ATs. Female distance runners were also sampled regarding policy in their athletic

departments or on their teams. Less than 10% of female distance runners indicated that their coaching staff and/or athletic departments have a policy in place that specifies what to do when an athlete presents with symptoms of the Triad and/or RED-S. In order to address disparities in knowledge and provide quality treatment for athletes, policies should be implemented at the institutional and team level to increase awareness and confidence of dealing with the Triad and RED-S within their teams. These exploratory variables should be further assessed in future research.

As previously explored in related mechanisms to knowledge and impact, access to adequate resources, funds, and appropriate medical professionals are issues faced across collegiate institutions. Knowledge, confidence, and impact scores significantly differed among female distance runners with positive Triad and RED-S diagnoses compared to female distance runners with negative Triad and RED-S diagnoses ($p < 0.01$). Knowledge and impact scores significantly differed among NCAA DI participants compared to non-DI participants in female distance runners and coaches ($p < 0.05$). Female distance runners participating in NCAA DI programs had the greatest access to certified sports dietitian(s). Female distance runners participating in NAIA programs had the least access to mental health specialist(s). As coaches and athletes, especially, rely on continuing education, often provided by their institutions, lack of access has possible far-reaching implications with regards to the treatment and prevention of the Triad and RED-S. Because knowledge did not significantly differ among division participation of ATs, this population may be less reliant on their institutions for formal education on these topics.

Limitations.

Despite our novel findings, there are limitations to the current study. The cross-sectional study design does not allow us to adequately explore the mechanisms of participant characteristics or educational training in a causal relationship to knowledge and impact. Thus, a longitudinal study design may provide insight into the role of participant characteristics to significant changes in knowledge and impact scores.

Additional limitations include selection bias of our participants, due to a low response rate (5.1%) and high participant mortality (23.7%) as illustrated in the flow diagram of participants (see: Appendix 4). These outcomes may demonstrate selection bias as only participants interested in the topic may have chosen to participate and provided complete data. The particularly low response rate in ATs, may reflect an increase bias for the selection of participants who responded to the questionnaire. As our target population was collegiate female distance runners and their support staff (coaches and ATs), this population may not fully represent the average of all collegiate athletes and support staff members. Extrapolation of results to other populations should be carefully considered.

Future Directions.

Our findings illustrate the knowledge, confidence, and impact of the Triad and RED-S in female distance runners, coaches, and ATs; however, more research is required to establish reference values for the scores. It is necessary to discern additional associations and potential reasons for significant differences in knowledge, confidence, and impact scores amongst participants. For instance, peak career mileage of female distance runners may correlate with increase impact scores because increased mileage may have caused symptomology related to the Triad or RED-S, leading to increase awareness and knowledge of the conditions. These relationships should be further explored in future investigations. Finally, educational training

programs should be developed and tested for increasing knowledge and impact in collegiate athletes and coaches. Educational training programs have been proven effective in other sports medicine topics, such as concussions, to increase awareness, knowledge, and treatment of athletes and support staff members[8]. Exploratory aims should be taken into consideration when considering future directions. Issues regarding confidence, policy, and access should be addressed and further explored in future studies. Implications of these issues may be far-reaching with respect to knowledge and were not controlled for in the present study.

In addition to the future directions of research of the Triad and RED-S, the exploratory variables should also be considered in informing next steps from an individual to institutional level. With the state of current research on the Triad and RED-S, educational programs and resources can be developed and delivered to athletes, coaches, ATs, and institutions. When surveyed, female distance runners indicated their primary needs to help in the presence of the Triad and RED-S to be as follows: 1) supportive, safe environments, 2) educational training for athletes, coaches, and other trained professionals, 3) access to professionals (e.g. RED-S practitioners, mental health specialists, registered sports dietitians) to provide care and treatment, and 4) more information and resources. All participants were surveyed about educational and institutional resources they would find valuable with respect to the Triad and RED-S. The primary educational resources participants value are as follows: 1) educational training (in-person or online), 2) presentations (in-person or online), 3) informational materials (e.g. website, pamphlets, academic journal articles, books, videos, podcast, forums), 4) appropriate medical professionals on staff (e.g. specialized physicians, registered sports dietitians, mental health specialists), and 5) guided activities (case studies, worksheets). The primary institutional resources participants value are as follows: 1) presentations (online or in-person), 2)

informational materials, 3) appropriate medical professionals on staff, 4) educational training (online or in-person), and 5) knowledgeable staff employed at institution. These positions and resources should be considered by athletic departments in order to improve the care of athletes through evidence-based informed practice and care of all members of their athletic communities (athletes, coaches, ATs, and other professionals).

Conclusion.

In the current study, we examined the knowledge, confidence, and impact of the Triad and RED-S amongst collegiate female distance runners, coaches of female distance runners, and ATs of collegiate female distance runners. We found that female distance runners had the lowest total impact scores and ATs had the highest total impact scores. The present study was unable to establish many meaningful, significant associations between participant characteristics, as potential mechanisms, and total scores of knowledge, confidence, and impact. However, the significant interaction of peak career mileage and Triad diagnosis in female distance runners reveals an important issue regarding the timing of educational training. Female distance runners with a positive Triad or RED-S diagnosis have higher impact scores likely due to their education from their physician and/or RD. Therefore, educational training should be aimed at being implemented prior to the development of the Triad and/or RED-S. In addition, educational training remains chiefly important in addressing the lack of sufficient knowledge in all study population groups, improving the prevention and treatment of the Triad and RED-S, and enacting meaningful policy at the institutional level to protect athletes in the face of these conditions. Future research is necessary to examine the mechanisms of participant characteristics in order to improve knowledge, as well as the most effective and efficacious methods of

educational training. In addition, action from an institutional level of all athletic members is necessary to improve the care of athletes.

Figure and Table Abbreviations:

The Triad = the Female Athlete Triad

RED-S = Relative Energy Deficiency in Sport

BSI = Bone Stress Injury

ATs = Athletic Trainers

NCAA = National Collegiate Athletic Association

mi./wk. = miles per week

DI = NCAA Division One

GA = Graduate Assistant

Table 1: Descriptive Characteristics and Scores (Knowledge, Confidence, and Impact)

	Female Distance Runners	Coaches of Female Distance Runners	ATs of Female Distance Runners
Age (yrs.)	20 ± 1.0	36 ± 11.0	34 ± 9.0
Total years of experience (yrs.)	8.95 ± 4.0	11.80 ± 7.8	11.6 ± 7.4
Years at present institution (yrs.)	3.25 ± 1.9	8.36 ± 6.9	8.40 ± 7.8
Current mileage (miles/week)	41.54 ± 15.3		
Peak career mileage (miles/week)	56.11 ± 12.9	71.27 ± 22.8	
BSI incidence	1.22 ± 1.8	1.37 ± 3.2	0.15 ± 0.8
Triad specific knowledge (%)	57.48 ± 28.7	66.70 ± 30.25	77.14 ± 22.0^*
Triad specific impact (%)	58.45 ± 21.65	68.06 ± 26.24^*	75.68 ± 21.03^*
RED-S specific knowledge (%)	70.52 ± 17.58#	70.93 ± 17.85	79.80 ± 17.43^*
RED-S specific impact (%)	61.41 ± 12.72	63.93 ± 15.07	70.66 ± 14.15^*
Total knowledge score	25.00 ± 5.27	26.92 ± 5.02^*	28.66 ± 4.02^*
Total confidence score	95.42 ± 28.83	111.35 ± 24.14^*	117.67 ± 22.53^*
Total impact score	18.81 ± 7.05	22.41 ± 6.33^*	23.93 ± 5.69^*

Table 1: A one-way ANOVA indicates significant differences between groups on: Triad specific knowledge, Triad specific impact, RED-S specific knowledge, RED-S specific impact, total knowledge scores, total confidence scores, and total impact scores. Paired samples T-tests indicates significant differences between groups on Triad specific scores and RED-S specific scores. Mean ± standard deviations, ^ $p < 0.05$ significance, *Versus female distance runners, #Versus Triad specific knowledge.

Table 2: Frequency Descriptive Characteristics

	Female Distance Runners (n)	Coaches of Female Distance Runners (n)	ATs of Female Distance Runners (n)
Female	175	26	26
Male	0	29	3
NCAA DI	97	30	13
NCAA DII	28	4	6
NCAA DIII	41	14	8
NAIA	9	7	3
Related academic area of study	27	8	30
Unrelated academic area of study	35	28	0
Head coach	n/a	23	n/a
Assistant coach	n/a	27	n/a
Graduate assistant coach	n/a	3	n/a

Table 2: Descriptive Statistics indicate the frequency of categorical variables among each population group.

Table 3: Pearson's Bivariate Correlations of Impact Score in Female Distance Runners

	n	Knowledge score (p-value)	Impact score (p-value)
Peak career mileage (mi./wk.)	175	0.173* (0.022)	0.195^ (0.010)
Total years of experience (running; yrs.)	175	0.055 (0.470)	0.084 (0.270)

Table 3: Pearson's bivariate correlations indicate significant correlations between female distance runners' characteristics and total impact and knowledge scores. ^ $p < 0.01$ significance, *$p < 0.05$ significance.

Table 4: Spearman's Bivariate Correlations of Impact Scores in Female Distance Runners

	n	Knowledge score (p-value)	Impact score (p-value)
Current mileage (mi./wk.)	175	0.115 (0.129)	0.125 (0.100)
Total BSI	171	0.077 (0.315)	0.074 (0.336)
BSI prevalence	86	0.077 (0.482)	0.104 (0.339)

Table 4: Spearman's bivariate correlations indicate non-significant correlations between female distance runners' characteristics and total impact scores. ^ $p < 0.01$ significance, *$p < 0.05$ significance. *Note: total BSI includes all participants self-reporting BSI diagnoses, BSI prevalence includes participants that have experienced one or more BSI.*

Table 5: Knowledge of Female Distance Runners across Division Participation

	n	Knowledge Score	Confidence Score	Impact score
DI participants	97	26.03 ± 5.33	98.56 ± 28.47	19.98 ± 7.05
Non-DI participants	78	23.73 ± 4.93^* (p = 0.004)	91.53 ± 28.97	17.35 ± 6.82* (p = 0.014)

Table 5: Independent Samples T-test indicates significant differences between division participation of female distance runners and total scores (knowledge, confidence, impact). Mean ± standard deviations, ^$p < 0.01$ significance; * $p < 0.05$ significance. *Versus DI participants

Table 6: Knowledge of Female Distance Runners across Academic Area of Study

	n	Knowledge score	Confidence Score	Impact score
Related academic area of study (i.e. exercise science, kinesiology, physiology)	27	26.6 ± 4.00	108.19 ± 19.44	21.91 ± 5.16
Unrelated academic area of study (i.e. business, marketing, communications)	35	22.70 ± 5.42* (p = 0.02)	87.77 ± 23.27^* (p = 0.001)	16.11 ± 5.54* (p = 0.000088)

Table 6: Independent Samples T-test indicates significant differences between female distance runners' academic area of study and total scores (knowledge, confidence, impact). Mean ± standard deviations, ^p < 0.01 significance; * p < 0.05 significance. *Versus participants with related academic area of study

Table 7: Knowledge of Female Distance Runners across Triad Diagnoses

	n	Knowledge score	Confidence Score	Impact score
Positive Triad diagnosis	77	26.52 ± 5.05	107.49 ± 20.97	21.69 ± 5.85
Negative Triad diagnosis	80	23.84 ± 4.92^ (p = 0.001)	87.61 ± 27.87^ (p = 0.000001)	16.80 ± 6.54^ (p = 0.000002)

Table 7: Independent Samples T-test indicates significant differences between female distance runners' Triad diagnoses and total scores (knowledge, confidence, impact). Mean ± standard deviations, ^$p < 0.01$ significance; * $p < 0.05$ significance. *Versus participants with positive Triad diagnosis

Table 8: Knowledge of Female Distance Runners across RED-S Diagnoses

	n	Knowledge score	Confidence Score	Impact score
Positive RED-S diagnosis	52	27.34 ± 5.30	109.15 ± 25.71	22.58 ± 6.82
Negative RED-S diagnosis	99	23.91 ± 4.96^ (p = 0.000125)	89.77 ± 27.03^ (p = 0.000036)	17.20 ± 6.34^ (p = 0.000003)

Table 8: Independent Samples T-test indicates significant differences between female distance runners' RED-S diagnoses and total scores (knowledge, confidence, impact). Mean ± standard deviations, ^$p < 0.01$ significance; * $p < 0.05$ significance. *Versus participants with positive RED-S diagnosis

Table 9: Pearson's Bivariate Correlations of Impact Scores in Coaches

	n	Knowledge score (p-value)	Impact score (p-value)
Age (yrs.)	55	0.076 (0.584)	-0.027 (0.845)
Total years of experience (coaching; yrs.)	55	-0.027 (0.843)	-0.116 (0.399)
Peak career mileage (mi./wk.)	55	0.231 (0.089)	0.161 (0.241)

Table 9: Pearson's bivariate correlations indicate non-significant correlations between coaches' characteristics and total impact and knowledge scores. ^$p < 0.01$ significance, *$p < 0.05$ significance.

Table 10: Spearman's Bivariate Correlations of Impact Scores in Coaches

	n	Knowledge score (p-value)	Impact score (p-value)
Total BSI	54	0.129 (0.352)	0.132 (0.342)
BSI prevalence	55	0.215 (0.407)	0.742 (0.056)

Table 10: Spearman's bivariate correlations indicate non-significant correlations between coaches' characteristics and total impact scores. ^$p < 0.01$ significance, *$p < 0.05$ significance.
Note: total BSI includes all participants self-reporting BSI diagnoses, BSI prevalence includes participants that have experienced one or more BSI.

Table 11: Knowledge of Coaches across Sex

	n	Knowledge score	Confidence score	Impact score
Female	29	27.00 ± 5.46	110.00 ± 27.29	24.16 ± 6.07
Male	26	26.82 ± 4.60	112.85 ± 20.48	22.44 ± 1.65

Table 11: Independent Samples T-test indicates non-significant differences between sex of coaches and total scores (knowledge, confidence, and impact). Mean ± standard deviations, * $p < 0.05$ significance. *Versus female participants

Table 12: Knowledge of Coaches across Academic Area of Study

	n	Knowledge score	Confidence score	Impact score
Related academic area of study (i.e. exercise science, kinesiology, physiology)	8	28.47 ± 5.59	112.13 ± 13.59	25.30 ± 5.60
Unrelated academic area of study (i.e. business, marketing, communications)	28	27.34 ± 3.77	113.50 ± 20.87	22.76 ± 5.19

Table 12: Independent Samples T-test indicates non-significant differences between coaches' academic area of study and total scores (knowledge, confidence, and impact). Mean ± standard deviations, * $p < 0.05$ significance. * Versus participants with related academic area of study

Table 13: Knowledge of Coaches across Coaching Position

	n	Knowledge score	Confidence score	Impact score
Head Coaches	23	27.15 ± 4.34	108.35 ± 23.26	21.78 ± 6.55
Assistant coaches (assistant, GA)	32	26.74 ± 5.52	113.50 ± 24.88	22.86 ± 6.24

Table 13: Independent Samples T-test indicates non-significant differences between coaches' position and total scores (knowledge, confidence, and impact). Mean ± standard deviations, * $p < 0.05$ significance. * Versus head coaches

Table 14: Knowledge of Coaches across Division Participation

	n	Knowledge score	Confidence score	Impact score
DI participants	30	27.82 ± 3.79	119.37 ± 15.72	24.13 ± 4.57
Non-DI participants	25	25.83 ± 6.09 (p = 0.144)	101.72 ± 28.90* (p = 0.006)	20.35 ± 7.55* (p = 0.026)

Table 14: Independent Samples T-test indicates significant differences between division participation of coaches and total scores (knowledge, confidence, and impact). Mean ± standard deviations, * $p < 0.05$ significance. *Versus DI participants

Table 15: Spearman's Bivariate Correlations of Impact Scores in ATs

	n	Knowledge score (p-value)	Impact score (p-value)
Age (yrs.)	30	-0.308 (0.098)	-0.097 (0.610)
Total years of experience (AT practitioner; yrs.)	30	-0.330 (0.075)	-0.064 (0.737)

Table 15: Spearman's bivariate correlations indicate non-significant correlations between ATs' characteristics and total impact and knowledge scores. ^$p < 0.01$ significance, *$p < 0.05$ significance.

Table 16: Knowledge of ATs across Sex

	n	Knowledge score	Confidence score	Impact score
Female	26	28.65 ± 4.20	118.50 ± 24.02	24.16 ± 6.07
Male	4	28.76 ± 2.96	112.25 ± 7.14	22.44 ± 1.65

Table 16: Independent Samples T-test indicates non-significant differences between sex of ATs and total scores (knowledge, confidence, and impact). Mean ± standard deviations, * $p < 0.05$ significance. *Versus female participants

Table 17: Knowledge of ATs across Division Participation

	n	Knowledge score	Confidence score	Impact score
DI participants	13	29.63 ± 4.29	120.15 ± 16.49	25.03 ± 5.18
Non-DI participants	17	27.93 ± 3.76	115.76 ± 26.59	23.08 ± 6.07

Table 17: Independent Samples T-test indicates non-significant differences between division participation of ATs and total scores (knowledge, confidence, and impact). Mean ± standard deviations, * $p < 0.05$ significance. *Versus DI participants

Table 18: Multivariate Analysis of Impact Scores in Female Distance Runners

	Type II Sum of Squares	Df	F	p-value	Partial Eta Squared	Observed power[a]
Division level participation	4.200	1	0.088	0.768	0.001	0.060
Peak career mileage	142.109	1	2.964	*0.087*	0.017	0.402
Peak career mileage * division level participation	0.231	1	0.005	0.945	<0.001	0.051
Triad diagnosis	539.312	1	15.114	<0.001*	0.090	0.971
Peak career mileage	230.270	1	6.453	0.012*	0.040	0.714
Triad diagnosis * Peak career mileage	296.492	1	8.309	0.005*	0.052	0.817

a. Computed using alpha = 0.05

Table 18: Univariate General Linear Model (GLM) indicates tests of between-subjects' effects and significant interaction(s) between the following variables: division level participation and peak career mileage, Triad diagnosis and peak career mileage. Mean ± standard deviations, *p < 0.05 significance.

Table 19: Multivariate Analysis Parameter Estimates of Impact Scores in Female Distance Runners

					95% Confidence Interval	
	B	Standard Error	t	p-value	Lower Bound	Upper Bound
Division level participation (= DI)	1.503	5.078	0.296	0.768	6.058	21.005
Peak career mileage	0.75	0.073	1.032	0.303	-0.069	0.220
Peak career mileage * division level participation (= DI)	0.006	0.091	1.032	0.945	-0.174	0.187
Triad diagnosis (= positive)	-16.746	4.307	-3.888	<0.001*	-25.256	-8.236
Peak career mileage	-0.013	0.053	-0.242	0.809	-0.117	0.091
Triad diagnosis (= positive) * Peak career mileage	0.215	0.075	2.883	0.005*	0.068	0.362

Table 19: Univariate General Linear Model (GLM) indicates parameter estimates and significant interaction(s) between the following variables: division level participation (= DI) and peak career mileage, Triad diagnosis (= positive) and peak career mileage. Mean ± standard deviations, * $p < 0.05$ significance.

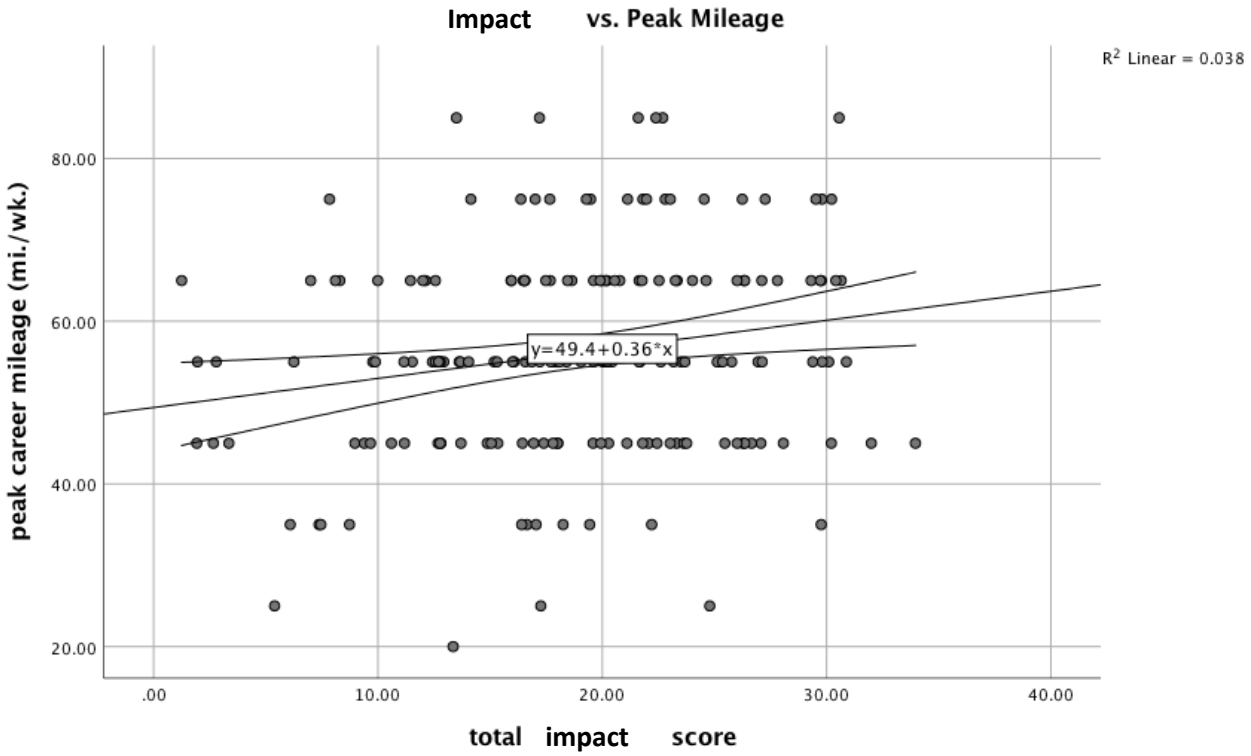

Figure 1: A Pearson's bivariate indicated that peak career mileage (mi./wk.) was significantly correlated with total impact scores in female distance runners (r = 0.195; *p =0.010).

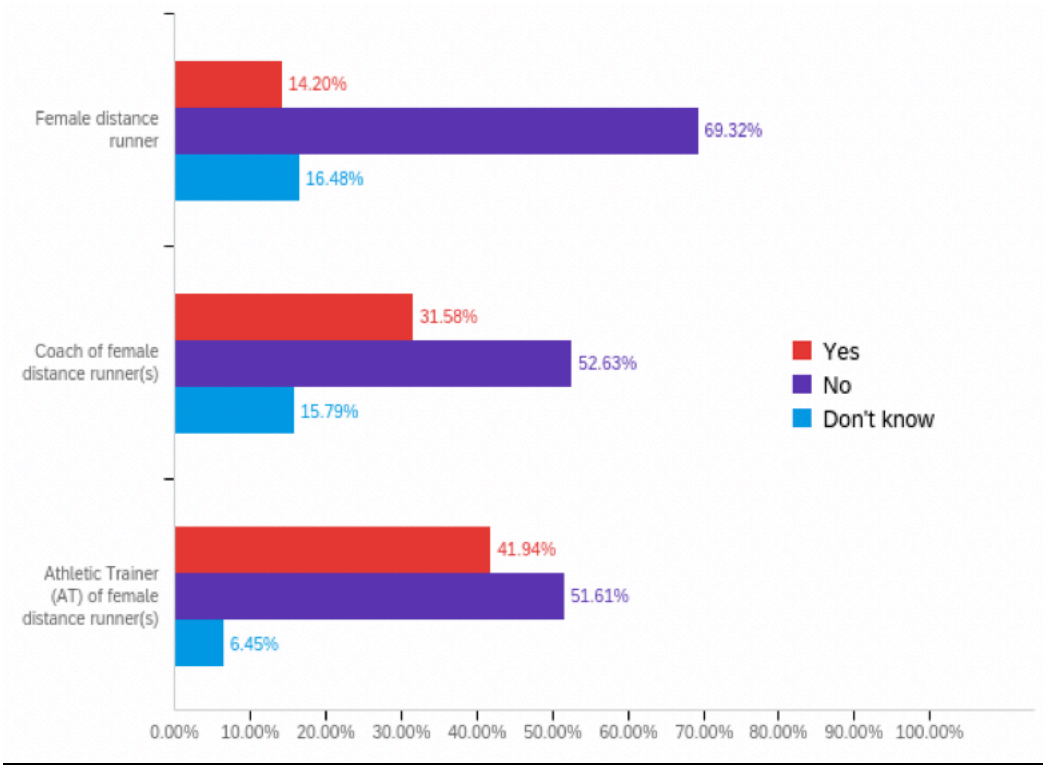

Figure 2: Bar chart indicating whether each population group received educational programming for athletes regarding the Triad and RED-S, provided by the athletic departments. *Note: No impact scores were associated (via independent samples T-tests) with educational programming provided by the athletic departments regarding the Triad and RED-S.*

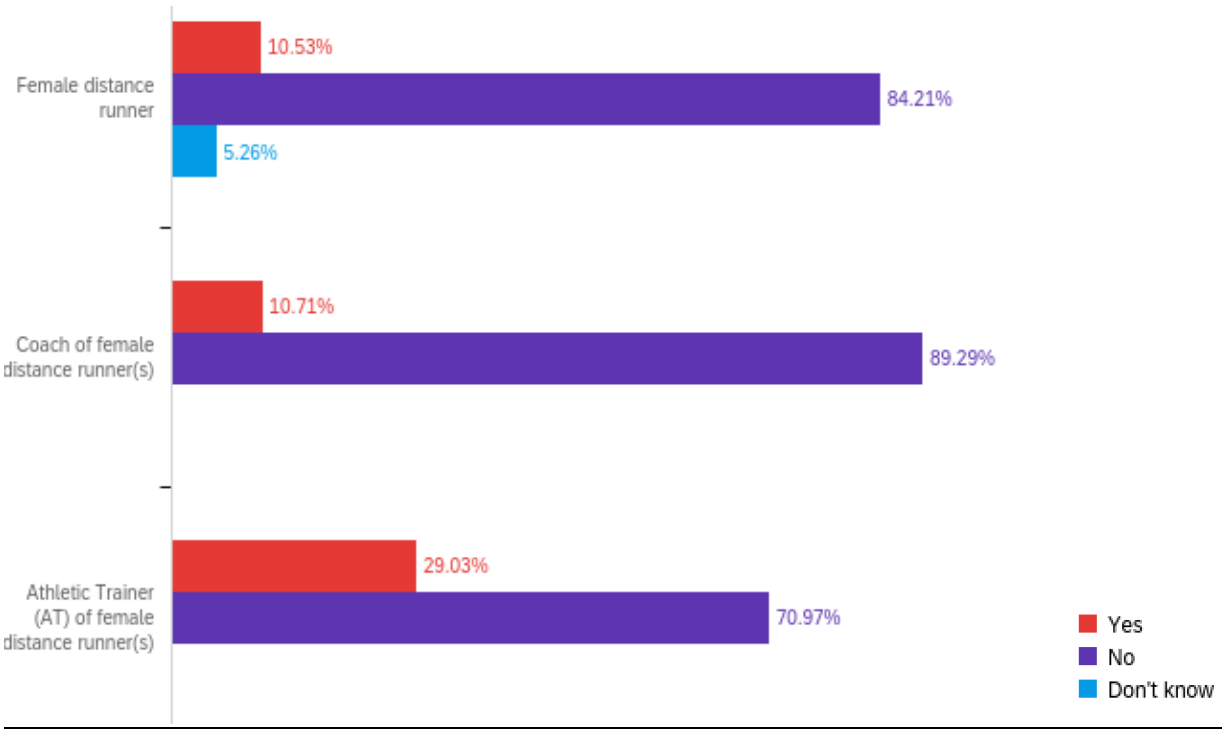

Figure 3: Bar chart indicating whether participants have received educational training through their current institution regarding the Triad and RED-S.

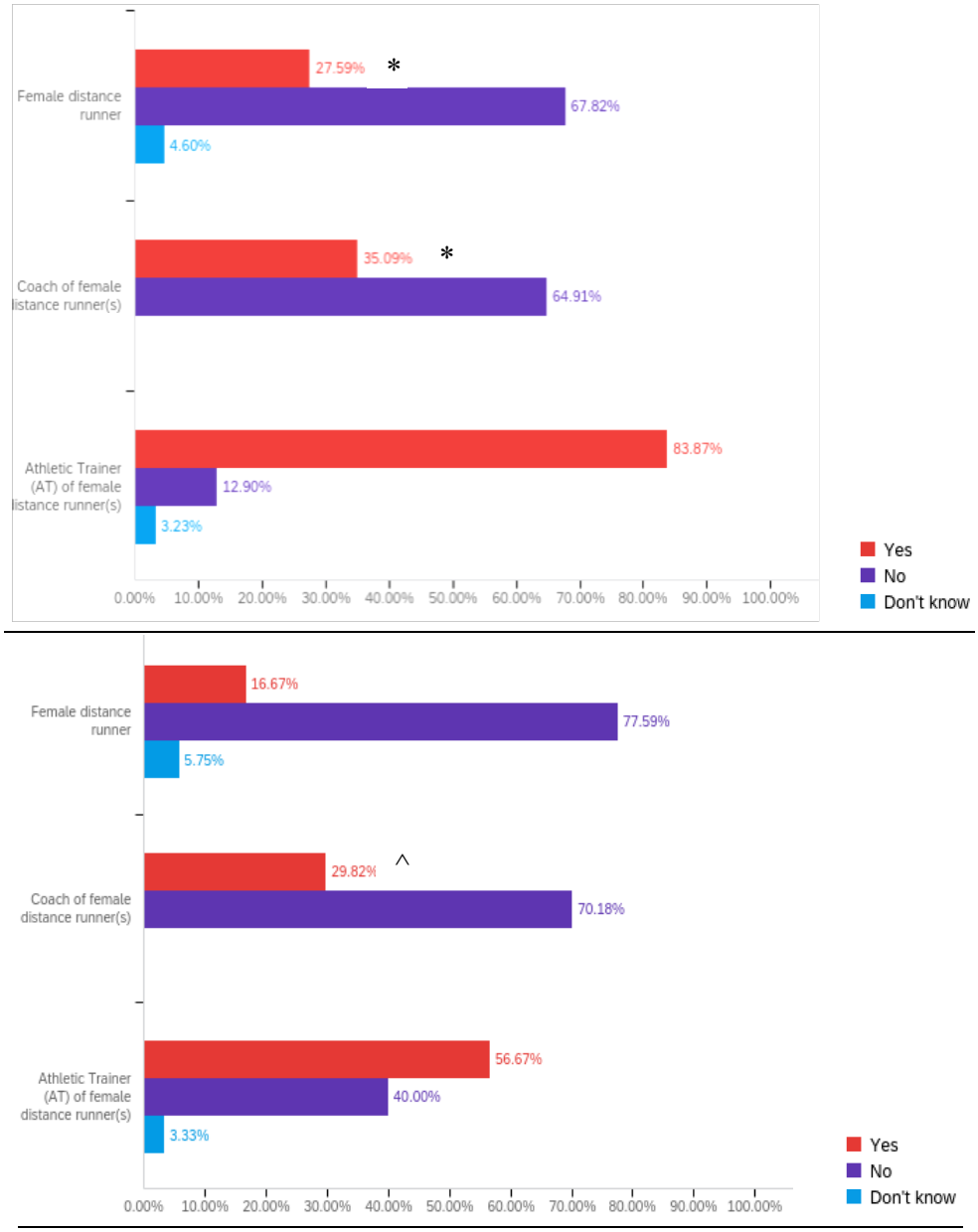

Figure 4: Bar chart indicating if each population group has received training on the subject of the Triad as a collective entity (TOP) or has received training on the subject of RED-S as a collective entity (BOTTOM). Assessment of impact scores via independent samples T-tests, ^$p < 0.01$ significance, *$p < 0.05$ significance. *Versus participants who did not receive training

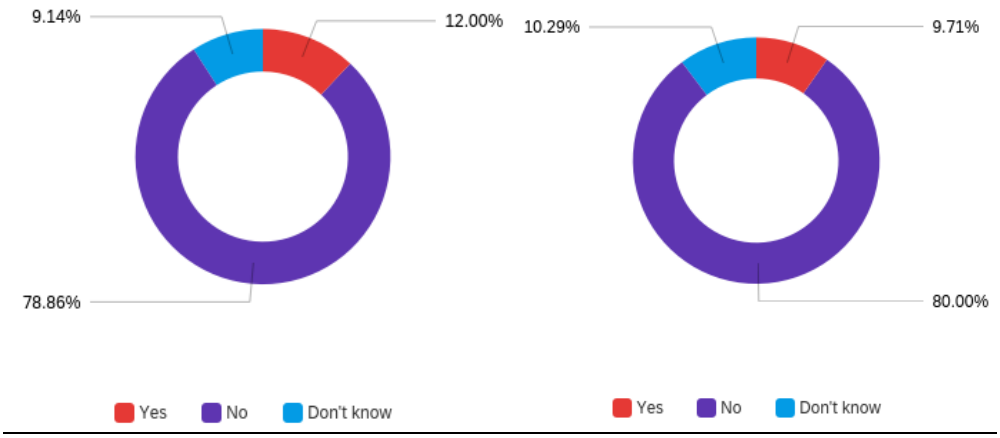

Figure 5: Pie graphs of knowledge translation provided by support staff, sampled from female distance runners. My coaching staff personally provides information for myself and teammates about the Triad and RED-S (LEFT). My AT(s) personally provides information for myself and teammates about the Triad and RED-S (RIGHT).

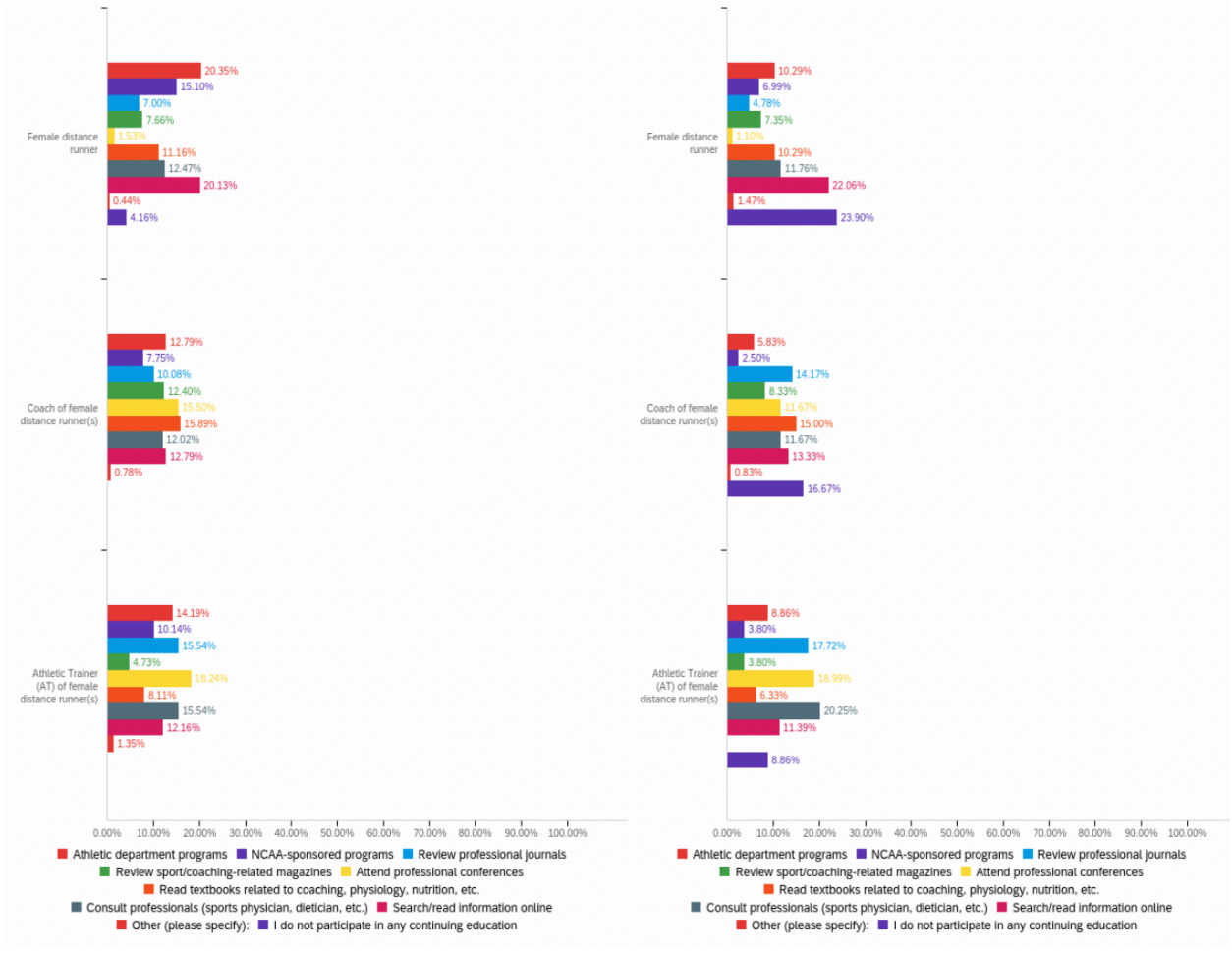

Figure 6: Bar chart indicating all type(s) of continuing education (left: general continuing education; n = 252) (right: Triad and/or RED-S specific continuing education; n = 247) that female distance runners (top), coaches (middle), and ATs (bottom) participate in at least once a year.

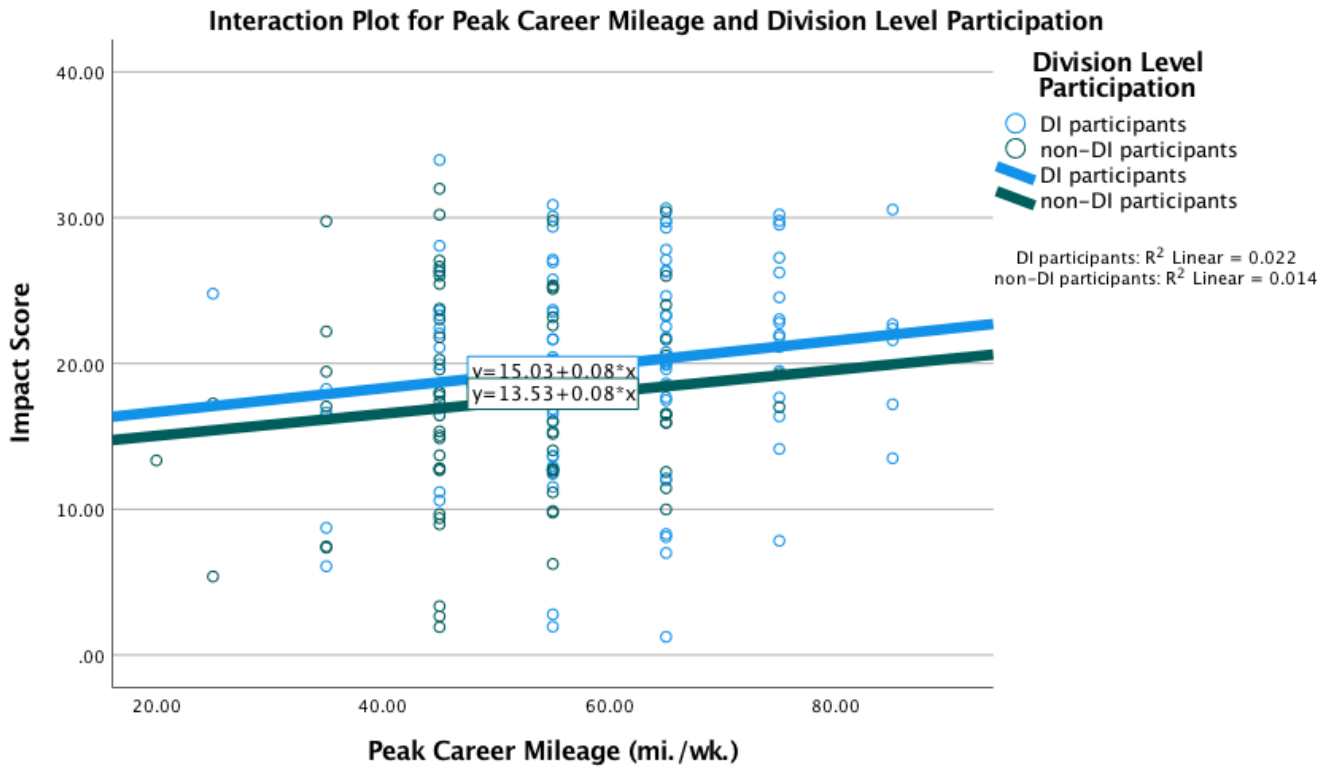

Figure 7: Interaction plot for peak career mileage (mi./wk.) and division level participation (DI participants vs. non-DI participants).

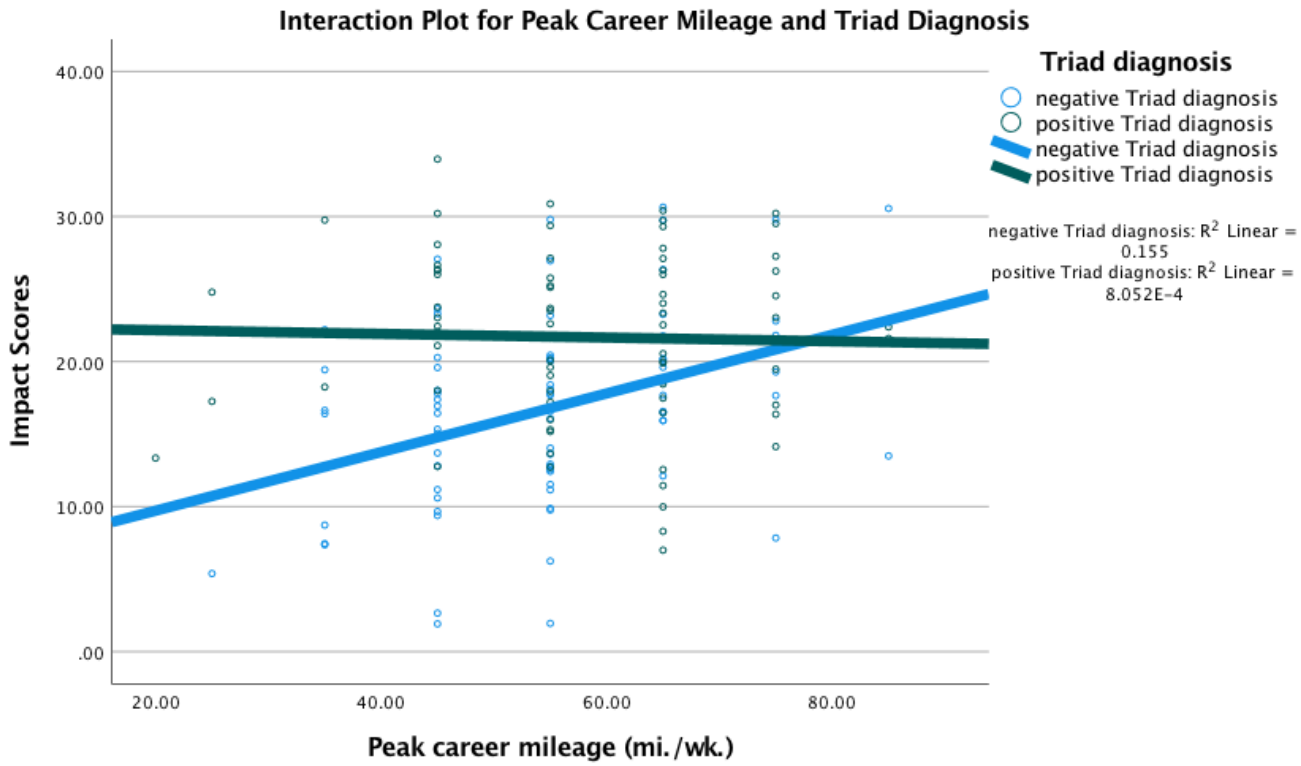

Figure 8: Interaction plot for peak career mileage (mi./wk.) and Triad diagnosis (positive Triad diagnosis vs. negative Triad diagnosis).

APPENDIX 1

Written Consent for the Triad and RED-S questionnaire (Online)

Start of Block: Informed Consent

Welcome to the research study!

The purpose of this form is to provide you with information about participation in a research study and offer you the opportunity to decide whether you wish to participate. You can take as much time as you wish to decide and can ask any questions you may have now, during or after the research is complete. Your participation is voluntary.

We are interested in understanding the knowledge, confidence, and training education of female distance runners and their support staff (specifically coaches and athletic trainers) with regards to the Female Athlete Triad (the Triad), as well as Relative Energy Deficiency in Sport (RED-S). You will be presented with information relevant to the Triad and RED-S and asked to answer some questions about it. Please be assured that your responses will be kept completely confidential. Our hope is that by investigating the knowledge, confidence, and education; we may better understand how to address these gaps in knowledge, such that we may be able to establish effective educational programming and better protect our female distance runners.

The study should take you around 15 minutes to complete. We ask that you answer each question to the best of your ability and that you do not receive any assistance while completing the questionnaire. This allows us to present the most reliable and efficacious data. Your participation in this research is voluntary. You have the right to withdraw at any point during the study, for any reason, and without any prejudice. If you would like to contact the Research Staff and/or Principal Investigator in the study to discuss this research, please e-mail Melissa Lodge at mlodge@syr.edu or Dr. Kevin Heffernan at ksheffer@syr.edu, respectively.

There are some risks associated with portions of this study. If at any point you are uncomfortable or anxious taking the questionnaire, you may skip and/or refuse to answer any question for any reason. Please contact the researcher(s) at any point if you have any questions or concerns. While we strive to maintain the highest level of confidentiality, it cannot be guaranteed in an internet setting. Whenever one works with email or the Internet there is always the risk of compromising privacy, confidentiality, and/or anonymity. Your confidentiality will be maintained to the degree permitted by the technology being used. It is important for you to understand that no guarantees can be made regarding the interception of data sent via the Internet via third parties. Your name will not appear anywhere on these computers or the data output from these computers. Your individual results will not be used in any way (we will average all results and display group averages only when presenting findings in papers and presentations).

There are no direct benefits to your participation in this study. You have the potential to benefit the society at large through your participation in this study. This study is exploring the knowledge, confidence, and education of female distance runners and their coaches/athletic trainers with respect to the Triad and RED-S. As female distance runners have a high susceptibility to these conditions, understanding any gaps in the knowledge of these individuals is paramount to establishing effective educational programming. The Triad and RED-S are highly prevalent in this athletic population and being able to more effectively educate these

populations may help maintain the health and safety of female distance runner in the future. You may feel good about helping others with their research study by participating in this research study.

By clicking the button below, you acknowledge that your participation in the study is voluntary, you are 18 years of age, and that you are aware that you may choose to terminate your participation in the study at any time and for any reason.

Please note that this survey will be best displayed on a laptop or desktop computer. Some features may be less compatible for use on a mobile device.

- I consent, begin the study
- I do not consent, I do not wish to participate

End of Block: Informed Consent

The Triad and RED-S Questionnaire

Start of Block: Participant Demographics

Q1 Sex:
- Male
- Female
- Other: _____

Q2 Age (in years): _____

Q3 Position:
- Female distance runner
- Coach of female distance runner(s)
- Athletic Trainer (AT) of female distance runner(s)

Q4 Level of participation in distance running:
- NCAA DI
- NCAA DII
- NCAA DIII
- NAIA

Q5 Total years of experience: *[i.e. years as a certified AT, years in a coaching position of female distance runner(s), years of training/competing as a female distance runner]*
- < 1 year
- 1-2 years
- 3-5 years
- 6-10 years
- 11-20 years
- 20+ years

Q6 Years spent at present institution and/or current level: *[years in a present coaching position of female distance runner(s), years of training/competing as a collegiate, female distance runner if currently in college]*
- < 1 year
- 1-2 years
- 3-5 years
- 6-10 years
- 11-20 years
- 20+ years

Display This Question:

If Position: = Coach of female distance runner(s)

Q7 Current position:

- Head coach
- Assistant coach
- Graduate Assistant (GA)
- Student (undergraduate) assistant

Q8 Race/Ethnicity:

- ☐ African American
- ☐ Asian or Asian American
- ☐ Caucasian
- ☐ Hispanic or Latino
- ☐ Native American
- ☐ Native Hawaiian or Pacific Islander
- ☐ Other: _____
- ☐ Prefer not to answer

Q9 Highest degree completed: *(please provide your major area of study and the year of completion)*

- High school diploma or GED
- Associate degree: _____
- Bachelor's degree: _____
- Master's degree: _____
- Doctoral degree: _____
- Other (please specify): _____

Q10 On average, how many miles do you CURRENTLY run per week (miles/week.)?

- Less than 20
- 20-29
- 30-39
- 40-49
- 50-59
- 60-69
- 70-79
- 80-89
- 90-99
- 100 or more

Q11 On average, what is/was your PEAK career weekly mileage (miles/week)?

- Less than 20
- 20-29
- 30-39
- 40-49

- 50-59
- 60-69
- 70-79
- 80-89
- 90-99
- 100 or more
-

Q12 Do you have a history of bone stress injury (stress reaction, stress fracture, etc.)?

- Yes
- No
- Don't know

Display This Question:

If Do you have a history of bone stress injury (stress reaction, stress fracture, etc.)? = Yes

Q13 If Yes, how many bone stress injuries have you been diagnosed with?

_____

Q14 Have you ever heard of the "Female Athlete Triad (the Triad)"?

- Yes
- No
- Don't know

Q15 Have you ever heard of "Relative Energy Deficiency in Sport (RED-S)"?

- Yes
- No
- Don't know

End of Block: Participant Demographics

Start of Block: Knowledge

Q16 The Female Athlete Triad (the Triad) consists of 3 components. Name as many as possible below:

- ☐ Component 1: menstrual irregularity (amenorrhea, menstrual dysfunction)
- ☐ Component 2: low energy availability (ED/DE, etc.)
- ☐ Component 3: low bone mineral density (bone-related consequence)

Q16b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0	1	2	3	4

Confidence	

Q17 The three components of the Female Athlete Triad are:

- disordered eating, anemia, low bone mineral density (BMD)
- anemia, menstrual irregularity, low energy availability
- menstrual irregularity, low energy availability, low bone mineral density (BMD)
- amenorrhea, osteoporosis, anemia

Q17b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q18 Those who can suffer from the Triad/RED-S include:

- young adult female athletes who have started to menstruate
- any physically active females
- adolescent female athletes
- A and C
- all of the above
- none of the above

Q18b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q19 Consequences of the Triad can affect a female:

- while she is still competing
- as long as she remains physically active
- for the rest of her life
- A and B
- all of the above
- none of the above

Q19b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q20 The MAIN cause of Relative Energy Deficiency in Sport (RED-S) is:

- ○ eating disorder(s)
- ○ amenorrhea
- ○ low energy availability
- ○ anemia

Q20b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q21 Select the *health* consequences of RED-S from the list below (select all that apply):

- ☐ Menstrual function
- ☐ Metabolic health
- ☐ Hematological health
- ☐ Cardiovascular health
- ☐ Psychological health
- ☐ Vitamin and mineral intake
- ☐ Bone health
- ☐ Electrolyte imbalance
- ☐ Immunological health
- ☐ Type II diabetes
- ☐ Growth and development
- ☐ Neurological health
- ☐ Endocrine health
- ☐ Musculoskeletal health
- ☐ Gastrointestinal health
- ☐ Insomnia
- ☐ Respiratory health

Q21b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q22 Select the *performance* consequences of RED-S from the list below (select all that apply):

- ☐ Decreased endurance performance
- ☐ Depression
- ☐ Infertility
- ☐ Increased response to training
- ☐ Increased injury risk
- ☐ Irritability
- ☐ Improved sport performance
- ☐ Decreased training response
- ☐ Insomnia
- ☐ Increased muscle strength
- ☐ Decreased muscle strength
- ☐ Impaired judgement
- ☐ Decreased coordination
- ☐ Decreased concentration
- ☐ Enhanced concentration
- ☐ Decreased glycogen stores
- ☐ Increased fine motor skill

Q22b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q23 Signs and symptoms of the Triad/RED-S can include (choose all that apply):

- ☐ dizziness
- ☐ stress fracture(s)
- ☐ depression
- ☐ hyperactivity
- ☐ fatigue
- ☐ low bone mineral density
- ☐ mealtime anxiety
- ☐ weight gain
- ☐ irritability
- ☐ sore throat
- ☐ abdominal pain
- ☐ knuckle scars
- ☐ dry hair & skin
- ☐ hypertension
- ☐ tachycardia (high resting heart rate)
- ☐ amenorrhea (lack of menstruation)
- ☐ oligomenorrhea (infrequent and/or light menstruation)

Q23b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

	0	1	2	3	4
Confidence					

Q24 Risk factors of the Triad/RED-S include (select all that apply):

- ☐ perfectionism
- ☐ resiliency
- ☐ chronic dieting
- ☐ negative self-talk
- ☐ positive body image
- ☐ competitive nature
- ☐ training outside scheduled practices
- ☐ low self-esteem
- ☐ good role models
- ☐ health approach to life and food
- ☐ adhering to certain meal plans
- ☐ feeling pressure to lose weight to improve performance
- ☐ commentary of bodies
- ☐ removal of social participation in team events
- ☐ participation in strength training

Q24b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

	0	1	2	3	4
Confidence					

End of Block: Knowledge

Start of Block: Knowledge pt. 2

Q25 Anorexia nervosa is characterized by the failure to maintain a normal weight for a person's age and height and an intense fear of gaining weight.

- ○ True
- ○ False
- ○ Don't know

Q25b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

	0	1	2	3	4
Confidence					

Q26 Individuals with bulimia nervosa can be almost any weight and often experience body image disturbance.

- True
- False
- Don't know

Q26b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence 

Q27 An excessive attention on healthy eating can be taken to the extreme, sometimes referred to as orthorexia, and is also a form of an eating disorder.

- True
- False
- Don't know

Q27b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence 

Q28 Orthorexia is not a health problem and just means that an athlete cares about their training/performances and wants to do well.

- True
- False
- Don't know

Q28b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence 

Q29 Amenorrhea involves the absence of three or more consecutive menstrual cycles.

- True
- False
- Don't know

Q29b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q30 Menstrual cycle disturbances, of any kind, are a normal part of training and there is nothing wrong with a female athlete losing her period.

- True
- False
- Don't know

Q30b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q31 Athletes must present with all aspects of the Triad/RED-S in order to be diagnosed with either of those conditions.

- True
- False
- Don't know

Q31b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q32 Osteoporosis is characterized by low bone mineral density which affects overall bone health.

- True
- False
- Don't know

Q32b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q33 Osteopenia (lesser degree of bone loss than osteoporosis), like osteoporosis, is directly affected by nutrition.

- True
- False
- Don't know

Q33b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q34 Eating disorders can be fatal.

- True
- False
- Don't know

Q34b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q35 Menstrual dysfunction in a college athlete generally has no bearing later in adult life.

- True
- False
- Don't know

Q35b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q36 Because of the impact of running on bone density, bone loss does not occur in many light-weight athletes.

- True
- False
- Don't know

Q36b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q37 Repeated stress fractures should serve as a warning with regards to low bone mineral density.

- True
- False
- Don't know

Q37b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q38 Eating disorders are caused exclusively by psychological problems.

- True
- False
- Don't know

Q38b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q39 College-aged athletes who suffer from low bone density can generally recuperate all bone loss later in life.

- True
- False
- Don't know

Q39b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q40 An athlete that suffers from the Triad will have a sudden, apparent decrease in sport performance.

- True
- False
- Don't know

Q40b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q41 As a coach, stressing an ideal weight helps an athlete understand how she can perform best in her sport.

- True
- False
- Don't know

Q41b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence

Q42 Joking comments made by others about one's weight can trigger disordered eating patterns in susceptible athletes.

- True
- False
- Don't know

Q42b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence

Q43 Once an athlete has a confirmed case of one of the three components of the Triad, screening for the other two components should follow.

- True
- False
- Don't know

Q43b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence

Q44 A coach's influence on the athlete extends to the behaviors and beliefs of the coach regarding weight issues.

- True
- False
- Don't know

Q44b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence

Q45 Prevention of the Triad involves emphasizing to athletes the amount of macro- and micronutrients that they need to compete as opposed to the foods they should avoid.

- True
- False
- Don't know

Q45b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q46 An efficient and easy way for medical staff to screen for the Triad involves using menstrual health history and nutritional history questionnaires.

- True
- False
- Don't know

Q46b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q47 The coaching staff member or the athletic trainer with the best relationship with the athlete is the person who should intervene when a case of the Triad/RED-S is suspected.

- True
- False
- Don't know

Q47b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q48 The intervention team should minimally involve a physician, dietitian, and a mental health specialist (i.e. psychiatrist or psychologist).

- True
- False
- Don't know

Q48b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q49 An athlete who is not getting their period should use a hormonal birth control in order to regain a normal menstrual cycle.

- True
- False
- Don't know

Q49b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q50 Certified dietitians are the best resource for athletes, coaches, and athletic trainers for nutritional advice.

- True
- False
- Don't know

Q50b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q51 Physicians are solely responsible for identifying the Triad/RED-S in athletes.

- True
- False
- Don't know

Q51b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

Q52 Athletes must manipulate their diet and weight in order to obtain their ideal “race weight”.

- True
- False
- Don't know

Q52b What is your confidence in your answer above? Confidence Scale: 1 = Not at all confident; 2 = Somewhat confident; 3 = Confident; 4 = Completely sure

0 1 2 3 4

Confidence	

End of Block: Knowledge pt. 2

Start of Block: Confidence

Display This Question:

If Position: = Female distance runner

Q53 Would you feel confident identifying the Triad/RED-S in yourself?

- Yes
- No
- Don't know

Display This Question:

If Position: = Female distance runner

Q54 Would you feel confident identifying the Triad/RED-S in a teammate?

- Yes
- No
- Don't know

Display This Question:

If Position: = Female distance runner

Q55 Would you feel confident self-reporting symptoms of the Triad/RED-S to a coach/athletic trainer?

- Yes
- No
- Don't know

Display This Question:

If Position: = Female distance runner

Q56 Would you feel confident talking/intervening with a teammate presenting with signs or symptoms of the Triad/RED-S?

- Yes
- No
- Don't know

Display This Question:

If Position: = Female distance runner

Q57 Would you feel confident seeking out help from an outside source (i.e. physician, registered dietitian, psychologist) if you thought you were suffering from the Triad/RED-S?

- Yes
- No
- Don't know

Q58 To the best of your knowledge, have you ever been diagnosed with the "Female Athlete Triad (the Triad)" or any of its' components?

- Yes
- No
- Don't know

Q59 To the best of your knowledge, have you ever been diagnosed with "Relative Energy Deficiency in Sport (RED-S)" or any of its' components?

- Yes
- No
- Don't know

End of Block: Confidence

Start of Block: Education

Display This Question:
If Position: = Female distance runner

Q60 My athletic department currently has a policy in place that specifies what to do when I suspect that I or a teammate may be suffering from one or more aspects of the Triad/RED-S.

- Yes
- No
- Don't know

Display This Question:
If Position: = Female distance runner

Q61 My coaching staff currently has a policy in place that specifies what to do when I suspect that I or a teammate may be suffering from one or more aspects of the Triad/RED-S.

- Yes
- No
- Don't know

Q62 The athletic department provides educational programming for the athletes about the Triad/RED-S.

- Yes
- No
- Don't know

Display This Question:
If Position: = Female distance runner

Q63 My coaching staff personally provides information for myself and teammates about the Triad and/or RED-S.

- Yes
- No
- Don't know

Display This Question:
If Position: = Female distance runner

Q64 My athletic trainer personally provides information for myself and teammates about the Triad and/or RED-S.

- Yes
- No
- Don't know

Display This Question:
If Position: = Female distance runner

Q65 I believe my coaching staff has a good understanding of the Triad/RED-S

- Yes
- No
- Don't know

Display This Question:
If Position: = Female distance runner

Q66 I believe my athletic trainer has a good understanding of the Triad/RED-S

- Yes
- No
- Don't know

Display This Question:
If Position: = Female distance runner

Q67 I believe my coaching staff has received educational programming about the Triad/RED-S.

- Yes
- No
- Don't know

Q68 I have received training on the subject of the Female Athlete Triad (the Triad) as a collective entity.

- Yes
- No
- Don't know

Q69 I have received training on the subject of Relative Energy Deficiency in Sport (RED-S) as a collective entity.

- Yes
- No
- Don't know

Q70 I am likely to prioritize training and performance over longevity and long-term health.

- Yes
- No
- Don't know

Q71 Indicate the type of **GENERAL** continuing education you take part in at least once a year *(check all that apply in general):* *the next question will ask about continuing education directly related to the Triad/RED-S; this is GENERAL continuing education only*

- ☐ Athletic department programs
- ☐ NCAA-sponsored programs
- ☐ Review professional journals
- ☐ Review sport/coaching-related magazines
- ☐ Attend professional conferences
- ☐ Read textbooks related to coaching, physiology, nutrition, etc.
- ☐ Consult professionals (sports physician, dietician, etc.)
- ☐ Search/read information online
- ☐ Other (please specify): _____
- ☐ I do not participate in any continuing education

Q72 Indicate the type of continuing education you take part in at least once a year **DIRECTLY RELATED** to the Triad/RED-S
(check all that apply specific to the Triad/RED-S):

- ☐ Athletic department programs
- ☐ NCAA-sponsored programs
- ☐ Review professional journals
- ☐ Review sport/coaching-related magazines
- ☐ Attend professional conferences
- ☐ Read textbooks related to coaching, physiology, nutrition, etc.
- ☐ Consult professionals (sports physician, dietician, etc.)
- ☐ Search/read information online
- ☐ Other (please specify): _____
- ☐ I do not participate in any continuing education

Q73 Are you aware of any resources available to you/your athletes regarding the Triad/RED-S through your current institution?

- ○ Yes
- ○ No
- ○ Don't know

Q74 Have you received training/educational programming through your current institution/employer regarding the Triad/RED-S?

- Yes
- No
- Don't know

Q75 If "Yes", which components have you received training/education for:

- Irregular menstrual cycles
- Low energy availability
- Bone mineral density
- Disordered eating/eating disorders
- Other: _____

Display This Question:

If Position: = Female distance runner

Q76 Do you have access to a certified sports dietitian?

- Yes
- No
- Don't know

Display This Question:

If Position: = Female distance runner

Q77 Do you have access to a mental health specialist (i.e. psychologist, psychiatrist, social worker)?

- Yes
- No
- Don't know
-

Q78 If your institution provided educational training for you with respect to the triad/RED-S, would you attend or take the course?

- Yes
- No
- Don't know

Q79 Why or why not would you attend or take the course? _____

Q80 If educational training with regards to the Triad and RED-S was required by your institution, would you prefer the training be online or in-person?

- Online
- In-person

End of Block: Education

Start of Block: Additional Commentary

Q81 What type of resources would you find valuable to educate yourself on these conditions?

_____

Q82 What type of resources would you like to see provided by your institution to help with these conditions?

_____

Display This Question:

If Position: = Female distance runner

Q83 What do you need as an athlete to help in the presence of these conditions?

_____

Q84 If you would like to provide any additional feedback, please leave your comments below:

_____

End of Block: Additional Commentary

Start of Block: Resources

I'm on the cross country team and in order to run faster I thought I should lose a few pounds. I decreased the calories I was eating and with an initial loss of weight my performance improved, but now I have gone four months without a period and I am always exhausted during workouts. Yesterday I was diagnosed with a stress fracture. Now, I'm worried about my health and performance.

As a female student-athlete, do I need to be aware of a larger issue?

THE FEMALE ATHLETE TRIAD DEFINED

Athletes who have low energy availability are more likely to have decreased estrogen levels and subsequent menstrual dysfunction and bone loss. Bone loss with the Triad during the college years is serious, as poor bone health increases injury risk, and the window for building bone density closes in early adulthood. While absence of menses may be common among female athletes, it is not healthy, and needs to be treated as any other medical concern. Intervening early is crucial for optimal recovery and to prevent potential long-term consequences.

(For consequences of sub-optimal fueling and tips for overall health, turn the page.)

Information presented by

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Female Athlete Series | Female Athlete Triad

Taking charge: from recovery to victory

Preventing the female athlete triad

Be aware of your risk. If you compete in weight-class sports and aim to reduce your weight before a competition, or if your sport emphasizes leanness or aesthetics, like gymnastics, ballet, figure skating, lightweight rowing or running, you may be at a higher risk. But keep in mind that any female athlete may suffer from components of the triad.

Recognize pressures and reach out for support. If you feel pressured to reduce your weight for a sport or to use harmful dieting methods before a competition, ask your doctor for help communicating with your coach and other athletic community members to prioritize your health.

Talk to your doctor (see below) about your weight, competitive pressures, menstrual cycle, stress fractures, exercise and eating habits and overall health.

Talking to your doctor

Even if you don't think you are experiencing an element of the triad, it's a good idea to talk to your doctor regularly about your exercise, eating and menstrual habits. Your pre-participation physical is a great opportunity to do this, since you may learn something new about yourself before your season begins.

TELL your doctor	ASK your doctor
if you experience even one element of the triad	about your risk of getting one of the three elements
if you have to monitor your weight for a sport	for healthy fueling techniques to increase your energy
if you fear weight gain	if you could benefit from a DXA (dual-energy x-ray absorbtiometry) test, which can measure your bone mineral density
if you have had a stress fracture	to speak to your coach if you need more support maintaining a healthy diet or activity level
if you've had irregular periods	

Boston Children's Hospital
Until every child is well

Reviewed by Kathryn Ackerman, MD, MPH, Boston Children's Hospital
This sheet is part of the Female Athlete Series, which is a suite of educational materials to help female athletes live the healthiest lives possible while competing. For more materials on enhancing athletic performance, call 617-355-3501 or visit bostonchildrens.org/sportsmed.

Female Athlete Series
Female Athlete Triad

Boston Children's Hospital
Sports Medicine
bostonchildrens.org/sportsmed
617-355-3501

Female athlete triad: Staying on track

The female athlete triad (triad) is a continuum of three intertwined health issues: energy availability (caloric balance), menstrual function and bone health.

At the positive end of the continuum, female athletes ingest enough quality calories to account for their energy expenditure from daily activities and exercise (energy availability); they have normal monthly menstrual cycles, and they have bone density that is equal to or better than their sedentary counterparts because of their weight-bearing exercise.

At the extreme negative end of the continuum, poor caloric intake combined with exercise and activity leads to low energy availability, which may lead to a loss of menstrual cycle, low bone density and, ultimately, osteoporosis. Low bone density and osteoporosis put athletes at risk for stress fractures and full fractures. Thus, a problem with any one aspect of the triad may be cause for concern.

Low energy availability

Female athletes—especially those involved in sports that emphasize leanness, like ballet, gymnastics, figure skating, lightweight rowing and running—are at risk for developing eating disorders because of pressures to maintain a low body weight, or because of poor guidance about nutrition and weight loss. Sometimes, this can lead to serious energy deficiency.

Fortunately, knowing the difference between healthy and harmful dieting can help ensure that the athlete gets optimal nutrition. Healthy dieting is considered a modest lowering of daily calories, while harmful dieting (or disordered eating) includes restrictive behaviors like skipping meals, using laxatives, bingeing and purging. Ideally, an athlete doesn't "diet" at all, because she has the tools to keep a healthy body weight and has the energy her athletic body needs to perform and function properly.

Low energy availability can result from full-blown eating disorders, or it may simply be that the athlete isn't getting the calories necessary for the high-caloric expenditure of sport.

***The prevalence of clinical eating disorders** among elite female athletes ranges from 16 to 47 percent, compared to the 10 percent of nonathletic females. Disordered eating and caloric deficiency are even higher. Maintaining healthful eating habits and a healthy mindset, and keeping a supportive network can help female athletes stay healthy.*

Boston Children's Hospital offers Sports Medicine care at locations in BOSTON, WALTHAM, LEXINGTON AND PEABODY, MA

RED-S CAT™

Relative Energy Deficiency in Sport (RED-S) Clinical Assessment Tool (CAT)

For use by medical professionals only

Name Date: Examiner:

What is the RED-S CAT?

The RED-S CAT is a clinical assessment tool for the evaluation of athletes/active individuals suspected of having relative energy deficiency and for guiding return to play decisions. The RED-S CAT is designed for use by a medical professional in the clinical evaluation and management of athletes with this syndrome. The RED-S CAT is based on the IOC Consensus Statement on RED-S, 2014.[1]

This tool may be freely copied in its current form for use by sport organizations and the athlete medical team entourage. Alterations to the tool or reproduction for publication purposes require permission from the International Olympic Committee.

NOTE: The diagnosis of RED-S is a medical diagnosis to be made by a trained health care professional. Clinical management and return to play decisions for athletes with RED-S should occur under the guidance of an experienced sports medicine team.

What is Relative Energy Deficiency in Sport?

The syndrome of RED-S refers to impaired physiological functioning caused by relative energy deficiency, and includes but is not limited to impairments of metabolic rate, menstrual function, bone health, immunity, protein synthesis, and cardiovascular health.

The cause of RED-S is the scenario termed "low energy availability", where an individual's dietary energy intake is insufficient to support the energy expenditure required for health, function, and daily living, once the cost of exercise and sporting activities is taken into account.

The potential health consequences of RED-S are depicted in the RED-S conceptual model (See Figure 1). Psychological problems can be both the result of and the cause of RED-S.

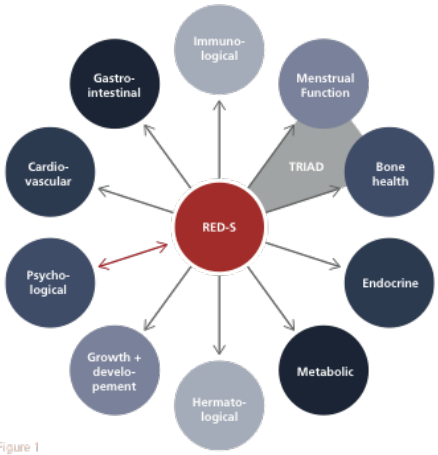


Figure 1

RED-S may also affect athlete sport performance. The potential effects of RED-S on sport performance are illustrated in Figure 2:

Figure 2

Screening for RED-S

The screening and diagnosis of RED-S is challenging, as symptomatology can be subtle. A special focus on the athlete at risk is needed. Although any athlete can suffer from RED-S, those at particular risk are those in judged sports with an emphasis on the aesthetic or appearance, weight category sports, and endurance sports. Early detection is of importance to maintain and improve performance and prevent long-term health consequences.

Screening for RED-S can be undertaken as part of an annual Periodic Health Examination and when an athlete presents with Disordered Eating (DE)/Eating Disorders (ED), weight loss, lack of normal growth and development, endocrine dysfunction, recurrent injuries and illnesses, decreased performance/performance variability or mood changes.

Br J Sports Med 2015;**49**:421–423. doi:10.1136/bjsports-2014-094559

Scoring Instructions

Calculating total impact score:

The scale combines knowledge and confidence. The total points of the survey impact score range between +37 and -37. Each question has a score range between +1 and -1. One point is the correct answer and high confidence and minus one point is the incorrect answer and high confidence. The score of the questions is reduced when the coach has lower confidence in their answer (Confidence 4 = 1 point, Confidence 3 = 0.75 points, Confidence 2 = 0.5 points, Confidence 1 = 0.25 points, and Confidence 0 = 0 points). The questions in the survey included in the total impact score are Q16 through Q52b; all additional survey data is supplementary to our understanding of knowledge and will not be included in the calculation for the total impact score.

Example:
- If the answer is correct with the highest confidence (4) it is scored as 1.
- If the answer is incorrect with the highest confidence (4) it is scored as -1.
- If the answer is correct with the lowest confidence (1), it is scored as 0.25.
- If the answer is incorrect with the lowest confidence (1) it is scored as -0.25.
- If the answer is "I don't know", or a confidence of 0 is selected, it is scored as zero.

Note (1): It is also possible to use a knowledge scale without considering the confidence or considering apart from the confidence. A total knowledge score will also be assessed without the factor of confidence.
Note (2): For questions of "choose all that apply" nature, each possible sub-answer is considered individually. Divide the number of possible answers by the point of the question.

Calculating the level of knowledge among respondents from total score:

The percentage is calculated using the limits -37 to +37 of the score (Range of 74 points). A score of 0 will have a percentage of 50%, a score of -37 will have 0% and a score of +37 will be 100%.

Additional survey data:

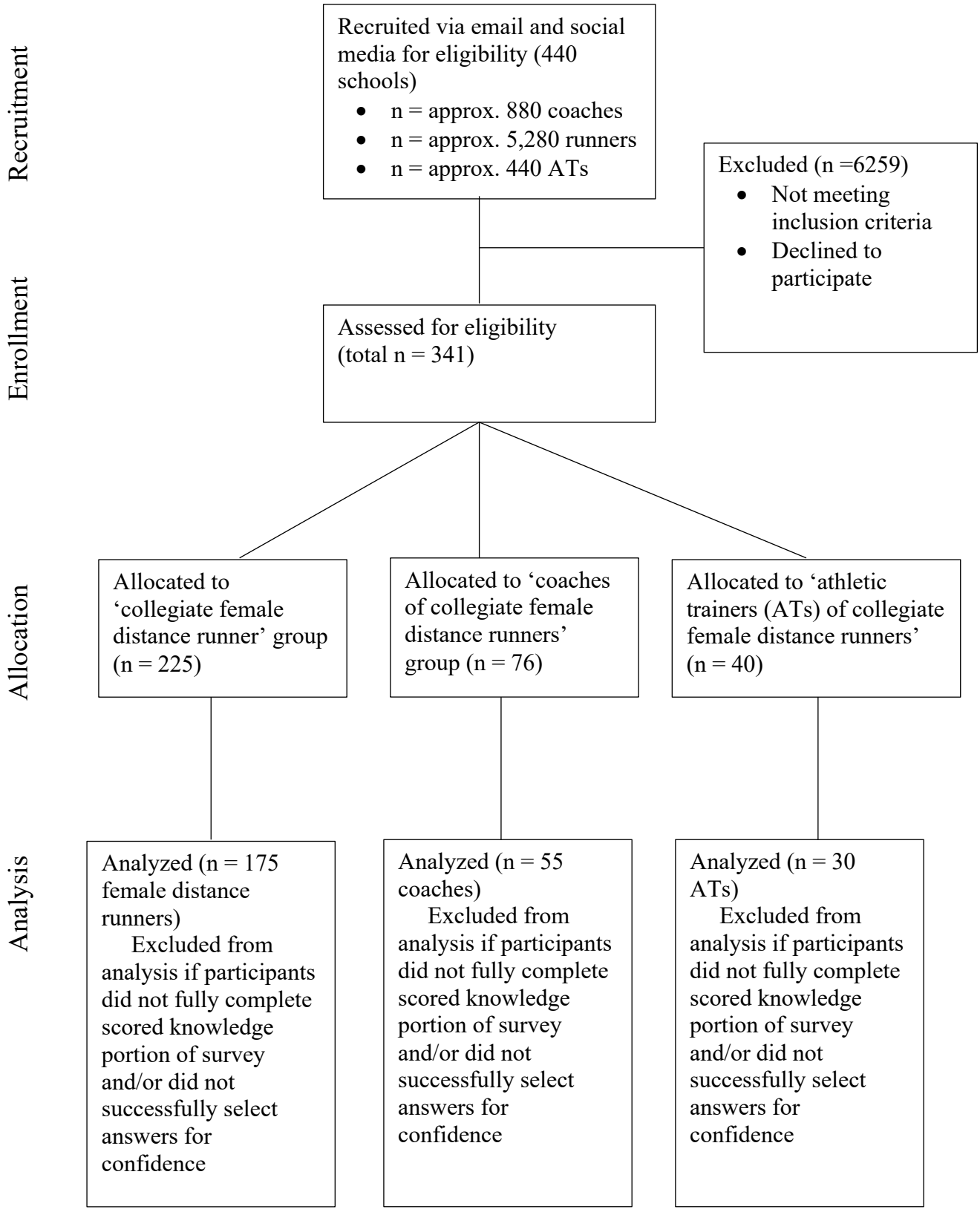
Additional survey data not included in the scoring indices will also be collected. Data based on participants characteristics and education are not included in the total score or level of knowledge. Questions not included in scoring index shall not affect the score of the respondent but may be helpful in interpreting scores and responses such that we found it valuable to include.

Range of scores to indicate the level of knowledge (high or low) among the respondents:

There is not enough data to establish reference values (high or low). More data is required to establish an evaluation of knowledge. More information can be found in this study and other values found in NCAA colleges of female athletes in the following articles:

Frideres, J. E., Mottinger S. G., & Palao, J. M. (2016). Collegiate coaches' knowledge of the female athlete triad in relation to their characteristics. Central European Journal of Sport Sciences and Medicine, 14(4), 55-56 [PDF][20].

Flow Diagram of the Progress of Participants through the phases of recruitment, enrollment, allocation, and analysis.



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Melissa T. Lodge

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EDUCATION

Syracuse University, Syracuse, NY **2018-2020**

- Master of Science in Exercise Science, August 2020
- Thesis: *Knowledge of the Female Athlete Triad and Relative Energy Deficiency in Sport Amongst Female Distance Runners and Their Support Staff*

Bryant University, Smithfield, RI **2015-2018**

- Bachelor of Science in Pre-Health Biology, May 2018
- Minors: Psychology, Human Resource Management
- Research Project: Exploring the Female Athlete Triad in USA vs. Australia

INTERNSHIP/WORK EXPERIENCE

Syracuse University, Department of Exercise Science **Fall 2019-Spring 2020**

Teaching Assistant

- Head instructor of recitation – teach sections, create lab work/assignments, grading, hold office hours, etc.
- Assist professor(s) with grading, lab work, meeting with students, etc.

Syracuse University Athletics **Fall 2019 - present**

Volunteer Assistant Coach – Women's Cross Country/Track & Field

- Work alongside head coach to assist in monitoring workouts, mentoring/meeting with student-athletes, overseeing resistance training program, team travel, etc.

Bowerman Sports Science Clinic, University of Oregon, Eugene, OR **Summer 2020**

Lab Assistant

- Data processer of biomechanical data using Cortex
- Other responsibilities include: RMR testing, VO_2 max testing, assistance with collecting pilot data

Ophelia's Place, Liverpool, NY **Spring 2020**

Student Ambassador Internship

- Responsibilities include informational interviews with expert in the field of ED recovery/prevention (with reflections), conducting awareness and fundraiser campaigns for Ophelia's Place
- Certification program: 4-month online course, designed to gain deeper understanding of ED prevention/intervention and strengthen sense of body respect, includes The Body Project training, certified Student Warrior for Change

Lane 9 Project **Spring 2019-present**

Online Writer

- Online writer for L9P, a volunteer-run, non-profit organization targeted at educating active women and girls on issues including women's health, eating disorder recovery, fertility, and sport.

Performance Physical Therapy, Smithfield, RI **Fall 2017**

Physical Therapy Shadow

ATHLETIC INVOLVEMENT

Division 1 Women's Cross Country/Track & Field Team, Syracuse University
Fall 2018-Spring 2019
Mid-Distance/Distance
Division 1 Women's Cross Country/Track & Field Team, Bryant University
January 2015-May 2018
Mid-Distance/Distance

SKILLS

Pre-Health

- Trained Facilitator for The Body Project®, a dissonance-based body acceptance program backed by NEDA
- Treadmill testing, cardiovascular measures, VO_2 max test/exercise prescription, body composition, graded exercise test (GXT), biomechanical analysis (Cortex)

Computer Skills

- Microsoft Office, Minitab, SPSS